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BULLETIN 662

MINERAL RESOURCES OF ALAS

REPORT ON PROGRESS OF
INVESTIGATIONS IN

1916

BY

ALFRED H. BROOKS AND OTHERS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1918

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

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MINERAL RESOURCES OF ALASKA, 1916.

By Alfred H. Brooks and others.

PREFACE.

By Alfred H. Brooks.

This volume is the thirteenth of a series of annual bulletins[1] treating of the mining industry of Alaska and summarizing the results achieved during the year in the investigation of the mineral resources of the Territory. In preparing these reports the aim is prompt publication of the most important economic results of the year. The short time available for their preparation does not permit full office study of the field notes and specimens, and some of the statements made here may be subject to modification when the study has been completed. Those interested in any particular district are therefore urged to procure a copy of the complete report on that district as soon as it is available.

This volume, like those previously issued, contains both preliminary statements on investigations made during the year and summaries of the condition of the mining industry, including statistics of mineral production. It is intended that this series of reports shall serve as convenient reference works on the mining industry for the years which they cover. Lack of funds prevents a visit to every mining district each year by a member of the Survey, and therefore the data used in preparing the summary on mining development are in part based on information gleaned from various reliable sources.

Again, as for many years in the past, the writer is under great obligation to residents of the Territory for valuable data. Those who have thus aided include the many mine operators who have made reports on production as well as developments. It is a matter of surprise and regret to the writer that there are still some Alaskan mineral producers who fail to respond to requests for information. Many prospectors, Federal officials, engineers, and officers of transportation and commercial companies have contributed valuable data. It is impracticable to enumerate all who have aided in this work, but it is right to state that without the assistance of these public-spirited citizens it would be impossible to prepare this report. Special acknowledgments should be made to the Director and other officers of the Mint; the officers of the Alaska customs service; Wells Fargo Express Co.; Thomas Riggs, jr., of the Alaskan Engineering Commission; the Alaska Mexican Gold Mining Co., Alaska United Gold Mining Co., and Alaska Treadwell Gold Mining Co., of Treadwell; B. L. Thane, F. B. Hyder, and J. Fazard, of Juneau; Stephen Birch, of Kennicott; George M. Esterly, of Nizina; W. Peterson and S. E. Wagner, of Susitna; A. H. McNeer, of Seward; G. R. Goshaw, and J. M. McLennan, of Chisana; J. L. Abrams, of Fortymile; John R. Kemp, of Steel Creek; J. J. Hillard and U. G. Myers, of Eagle; F. A. Reynolds, of Circle; R. C. Wood, A. Bruning, J. A. Fairborn, Falcon Joslin, First National Bank, American National Bank, and Tanana Valley Railroad, of Fairbanks; E. E. James, of Richardson; G. W. Ledger, of Rampart; S. S. Rowell, of Hot Springs; W. A. Vinal, H. Fothergill, and Henry Howard, of Ophir; C. P. Wood, of Iditarod; J. C. Felix, of Hughes; O. R. Williams, of Nolan; P. T. Hanigsman, of Bethel; William Loiselle and A. Steiker, of Quinhagak; R. W. J. Reed and G. A. Adams, of Nome; and John D. Flannigan, of Council.

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[1] The preceding volumes in this series are U. S. Geol. Survey Bulls. 259, 284, 314, 345, 379, 442, 480, 520, 542, 592, 622, and 642.

The arrangement and manner of treatment in this volume are the same as in those previously issued. First, papers of a general character are presented, followed by those treating of special districts, arranged geographically from south to north. This bulletin contains 15 papers by 11 authors. One of these papers deals with administrative matters, one is a general summary of the mining industry, and the remainder deal more specifically with the mineral resources of certain districts. In the geologic papers emphasis is laid on the conclusions that are of immediate interest to the miner. These conclusions are discussed here briefly but will be more fully treated in reports now in preparation. The need of prompt publication requires that the illustrations in this volume be of the simplest kind.

ADMINISTRATIVE REPORT.

By Alfred H. Brooks.

INTRODUCTION.

Twelve parties were engaged during 1916 in Alaska surveys and investigations. The length of field season ranged from 3 to 12 months, being determined by the character of the work and by the climatic conditions prevailing in different parts of the Territory. The parties included 11 geologists, 4 topographers, 1 engineer, and 28 packers, cooks, and other auxiliaries. Seven of the parties were engaged in geologic surveys, three in topographic surveys, one in combined topographic and geologic work, and one in stream gaging. The areas covered by reconnaissance geologic surveys on a scale of 1:250,000 (4 miles to an inch) amount to 5,100 square miles; by detailed geologic surveys on a scale of 1:62,500 (1 mile to an inch), 636 square miles. Much of the time of the geologists was devoted to the investigation of special problems relating to mineral occurrence, the results of which can not be expressed in terms of area. About 9,700 square miles was covered by reconnaissance topographic surveys, on a scale of 1:250,000 (4 miles to the inch), and 65 square miles by detailed topographic surveys, on a scale of 1:62,500 (1 mile to an inch). In cooperation with the Forest Service, stream gaging in southeastern Alaska was also continued.

With increased knowledge of Alaska's geology and the new facts made available by mining operations, it has become necessary to revise some of the previous interpretations of the geology, especially those made before accurate base maps were available. Therefore the revision of some of the mapping of the earlier years is of vital importance, and to this work some of the investigations of each year are devoted. In 1916 an area of 36 square miles adjacent to Juneau, previously surveyed geologically on a scale of 1:62,500, was mapped on the larger scale of 1:24,000. The geologic mapping of about 1,500 square miles on a scale of 1:250,000 was also revised.

To state the work geographically, four parties worked in southeastern Alaska, one in the Copper River region, two on Prince William Sound, four in the Yukon basin, and one in general investigations in the Yukon basin and Seward Peninsula. Among the important results of the year were the completion of the detailed topographic and geologic survey of Juneau and vicinity, the completion of the reconnaissance geologic survey of the southern part of the Ketchikan district, and the detailed geologic survey of a part of the Nenana coal field.

The following table shows the allotments, including both field and office work, of the total appropriation of $100,000 for the fiscal year 1916 to the regions investigated. In addition to this, a balance of about $6,000 from last year's appropriation was expended in equipping parties for the season's field work. In preparing this table the general office expenses are apportioned to the several allotments, account being taken of variations in character of work. The results are expressed in round numbers. Salaries of the permanent staff are included up to the end of the fiscal year 1917, but expenses other than these include only the cost of field and office work during 1916. The "general investigations" include, with other things, the cost of collecting mineral statistics and of office work relating to the field investigations of previous seasons. A balance of about $6,000 will be utilized for equipping the field parties in 1917.

Approximate geographic distribution of appropriation for Alaska investigations, 1916.

Southeastern Alaska	$22,500
Copper River	7,000
Prince William Sound	14,500
Yukon basin	42,500
Seward Peninsula	1,000
General investigations	6,500
To be allotted to field work, 1917	6,000
	100,000

In the following table the approximate amount of money devoted to each class of investigations and surveys is indicated. It is not possible to give the exact figures, as the same party, or even the same man, may have carried on the different kinds of work, but this statement will serve to elucidate a later table, which will summarize the complete areal surveys.

Approximate allotments to different kinds of surveys and investigations, 1916.

Reconnaissance geologic surveys	$15,000
Detailed geologic surveys	20,000
Special geologic investigations	11,600
Reconnaissance topographic surveys	19,000
Detailed topographic surveys	4,500
Investigations of water resources	4,900
Collection of mineral statistics	1,600
Miscellaneous, including administration, inspection, clerical salaries, office supplies and equipment, and map compilation	17,400
To be allotted to field work, 1917	6,000
	100,000

Allotments for salaries and field expenses, 1916.

Scientific and technical salaries	$39,843
Field expenses	37,615
Clerical and office salaries	16,542
To be allotted to field work, 1917	6,000
	100,000

The following table exhibits the progress of investigations in Alaska and the annual grant of funds since systematic surveys were begun in 1898. It should be noted that a varying amount is spent each year on special investigations that yield results which can not be expressed in terms of area.

Progress of surveys in Alaska, 1898–1916.

Year.	Appropriation.	Areas covered by geologic surveys.			Areas covered by topographic surveys.[a]					Investigations of water resources (gaging stations maintained part of year).
		Exploratory (scale 1:625,000 or 1:1,000,000).	Reconnaissance (scale 1:250,000).	Detailed (scale 1:62,500).	Exploratory (scale 1:625,000 or 1:1,000,000).	Reconnaissance (scale 1:250,000; 200-foot contours).	Detailed (scale 1:62,500 and larger; 25, 50, or 100 foot contours).	Lines of levels.	Bench marks set.	
		Sq. m.	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Miles.*		
1898	$46,189	9,500	....	....	12,840	2,070	....	....	....	....
1899	25,000	6,000	....	....	8,690	....	....	....	....	....
1900	60,000	3,300	6,700	....	630	11,150	....	....	....	....
1901	60,000	6,200	5,800	....	10,200	5,450	....	....	....	....
1902	60,000	6,950	10,050	....	8,330	11,970	96	....	....	....
1903	60,000	5,000	8,000	96	....	15,000	....	....	....	....
1904	60,000	4,050	3,500	....	800	6,480	480	86	19	....
1905	80,000	4,000	4,100	536	....	4,880	787	202	28	....
1906	80,000	5,000	4,000	421	....	13,500	40	....	....	14
1907	80,000	2,600	1,400	442	....	6,120	501	95	16	48
1908	80,000	2,000	2,850	604	....	3,980	427	76	9	53
1909	90,000	6,100	5,500	450	6,190	5,170	444	....	....	81
1910	90,000	....	8,635	321	....	13,815	36	....	....	69
1911	100,000	8,000	10,550	496	....	14,460	246	....	....	68
1912	90,000	....	2,000	525	....	....	298	....	....	69
1913	100,000	3,500	2,950	180	3,400	2,535	287	....	....	....
1914	100,000	1,000	7,700	325	600	10,300	10	....	....	....
1915	100,000	....	10,700	200	....	10,400	12	3	2	9
1916	100,000	....	5,100	636	....	9,700	67	....	....	20
	1,461,189	73,200	99,535	5,232	51,680	146,980	3,731	453	74	....
Percentage of total area of Alaska	....	12.48	16.80	0.89	8.81	25.05	0.64	....	....	....

---

[a] The Coast and Geodetic Survey, International Boundary Survey, and General Land Office have also made topographic surveys in Alaska. The areas covered by these surveys are of course not included in these totals.

GEOGRAPHIC DISTRIBUTION OF INVESTIGATIONS.

GENERAL WORK.

The writer was engaged in office work until July 24, when he started for Alaska. He joined Mr. Chapin at Ketchikan on August 2 and devoted the next two weeks to a study of the geology of the Ketchikan district. The time from August 19 to 26 was spent in the Juneau district with Mr. Spencer and Mr. Eakin. Here a conference was also had with Mr. Canfield. A study of the geology of the Latouche district of Prince William Sound was made in company with Mr. Johnson from August 30 to September 10. A brief visit was then made to Anchorage, and several more days were spent at Juneau on the return trip. Seattle was reached on September 24.

During the calendar year 1916 the writer devoted 56 days of his time in the office to geologic studies, 24 days to the critical reading and revision of manuscripts, 13 days to the writing of the progress report, 10 days to field plans, 8 days to mineral statistics, 5 days to proof reading, and 4 days to preparation of the annual press bulletin on mining in Alaska.

Besides doing his field work, to be referred to below, G. C. Martin devoted considerable time to continuing the preparation of a monograph on the Mesozoic rocks of Alaska. The writer was absent from the office for the month of May, and during this time Mr. Martin was engaged chiefly in executive work as acting geologist in charge of the division.

R. H. Sargent continued the general supervision of the Alaska topographic surveys and map compilation, in addition to carrying on his own field work.

E. M. Aten continued as office assistant to the geologist in charge and supervised the office work during the writer's absence in the field. He also continued to assist in collecting statistics of production of precious metals in Alaska.

During the last six years J. W. Bagley has been investigating the use of phototopographic methods in Alaska surveys. He has devised both methods and instruments in this work, the utility of which has been proved by actual use. During 1916 he prepared a report containing the results of this work (see p. 10), which is intended for those who may find use for phototopographic methods in other fields.

SOUTHEASTERN ALASKA.

The geologic reconnaissance survey of the southern half of the Ketchikan district, begun in 1913 and continued in 1915, was completed in 1916. These investigations were made by Theodore Chapin, who devoted the time between May 20 and September 20 to the work.

In addition to revising the previous geologic mapping, an area of about 500 square miles was surveyed on a reconnaissance scale. Considerable time was also devoted to a study of the ore deposits and investigation of mining developments. An account of the latter is contained in another part of this report.

The making of a detailed base map of the region adjacent to Juneau, which was begun in 1914, was completed in 1916. The large scale adopted, 1:24,000 (about 2.64 inches to the mile), the ruggedness of the region, and the heavy timber and adverse climatic conditions have made this survey exceedingly difficult and expensive. The area covered is 36 square miles, of which 12½ square miles was surveyed in 1916. Owing to the high cost of the survey it has been necessarily confined to those areas which are of greatest present economic importance. D. C. Witherspoon, who did this work, was engaged in field work from May 29 to September 27, inclusive.

The area covered by the base map above referred to was surveyed geologically during 1916 by A. C. Spencer and H. M. Eakin, who also made a detailed investigation of the ore deposits. Field work was begun on July 11 and continued until October 6, covering an area of 36 square miles. Mr. Eakin also devoted about three weeks to a study of the Porcupine placer district. This district had not been investigated by a geologist since 1903, and in that time some new developments had been made. Mr. Eakin also devoted about a week to collecting data on mining developments in the less accessible parts of the Juneau district. The results of these two investigations are summarized in another part of this volume.

The investigation of the water resources of southeastern Alaska, begun in 1915 under a cooperative agreement with the Forest Service, was continued throughout 1916. G. H. Canfield, who had charge of this work, maintained 8 automatic gages throughout the year. In addition to these gages 12 others were installed in cooperation with different individuals and corporations. The results are briefly summarized in another section of this report. This work could not have been carried on without the cordial cooperation of the Forest Service, many members of which have given substantial aid; particular acknowledgment should be made to W. G. Weigle, special agent at Ketchikan, and to Leonard Lundgren, district engineer at Portland Oreg.

COPPER RIVER REGION.

Though much the larger part of the Chitina basin has been covered by geologic surveys, there are still many unsolved problems relating to the stratigraphy, structure, and ore deposits. These can be solved only by a more or less intensive study of special areas, and to this task F. H. Moffit was assigned. He devoted the time from June 23 to September 29 to this work. In addition to making a special study he also made geologic reconnaissance surveys of about 300 square miles. The preliminary report of the results of this work is contained an another part of this volume.

PRINCE WILLIAM SOUND.

The rapid development of mining in the Prince William Sound region has made a demand for further surveys and investigations. During 1916 B. L. Johnson made a somewhat detailed survey of the Latouche district, in which he covered an area of about 400 square miles. He also made some investigations of the mining developments in other parts of the Prince William Sound region, the results of which are presented in another part of this volume. Mr. Johnson devoted the time from June 11 to October 18 to this work.

J. W. Bagley began topographic reconnaissance surveys in the Port Wells district of the Prince William Sound region on June 8 and extended these surveys eastward, continuing his field work until September 12. He covered an area of 1,900 square miles on a scale of 1:250,000, using phototopographic methods. In addition to this, he surveyed in detail (scale 1:62,500) an area of 65 square miles lying adjacent to Jack Bay, this work connecting the previously mapped areas of the Ellamar and Port Valdez districts.

YUKON BASIN.

G. C. Martin, assisted by A. G. Maddren and R. M. Overbeck, made a detailed geologic survey of the western part of the Nenana coal field. The base map was provided for this work by the surveys made by the General Land Office. The field work extended from June 16 to August 24, and the total area surveyed was 236 square miles on a scale of 1:62,500.

S. R. Capps and C. E. Giffin were charged with the duty of making a reconnaissance survey of the Kantishna placer district. The surveys were begun on Nenana River and were extended eastward to include the Kantishna district and southward to the crest line of the Alaska Range. Mr. Capps, who had charge of the geologic investigations, began work on June 26 and continued until August 25, surveying an area of about 1,000 square miles on a scale of 1:250,000. He also revised previous geologic mapping over an area of about 2,000 square miles. The preliminary report of the results of this work is contained in another part of this volume. Mr. Giffin began the topographic survey on June 26 and completed it on August 29. He covered an area of 4,500 square miles, using phototopographic methods.

The important developments in the Tolovana district led to an investigation of this field during 1916. J. B. Mertie, jr., who was detailed for this investigation, began field work on July 7 and continued until August 4. Besides studying the placers he made a geologic reconnaissance map of about 240 square miles. The time from August 8 to 31 was devoted by Mr. Mertie to an investigation of the ore deposits of the Fairbanks district. In this field he devoted special attention to the occurrence of tungsten. The results of these investigations are presented elsewhere in this volume.

Important mining developments in the Marshall district of the lower Yukon have made an urgent demand for a survey of this field. Therefore a combined geologic and topographic party under the direction of R. H. Sargent, with G. L. Harrington as geologist, was assigned to this field. This party began work on June 16 and continued until September 6. The topographic and geologic surveys cover an area of some 3,300 square miles. The results of the study of the placers are presented elsewhere in this volume.

SEWARD PENINSULA.

J. B. Mertie, jr., was detailed to make a supplementary investigation of the lodes in the Nome and other districts of the Seward Peninsula. He devoted the time from September 19 to October 13 to this work and paid special heed to the tungsten and antimony deposits. In addition he collected data on mining developments. The results of his work are presented elsewhere in this volume.

COLLECTION OF STATISTICS.

The collection of the statistics of precious metal production in Alaska, begun by the writer in 1905, has been continued each year. In spite of every effort made there are still a large number of mine operators who fail to make returns. This is to the great disadvantage of the mineral industry, as it decreases the accuracy of the figures on production for the different districts. Fortunately other sources of information are available, and, thanks to the public spirit shown by many residents of the Territory, it is possible to obtain data on which reliable estimates of mineral production can be based. Until all the mine operators make returns, however, it is not possible to obtain entirely accurate figures. The nonreporting operators are chiefly placer miners, for practically all the gold and copper lode operators make annual returns of output.

As has been the practice in the past, a press bulletin was issued on January 1 summarizing the estimates of mineral production and mining developments of the previous year. Though the figures of production then published vary somewhat from the final figures included in this report, yet they were near enough to the truth to serve the immediate purpose of those interested in the mining industry of Alaska. The prompt publication makes the data available when most needed.

PUBLICATIONS.

During 1916 the Survey published four bulletins and one water-supply paper relating to Alaska. In addition, one bulletin is in press, and twelve reports, including this volume, were in progress at the end of the year. Two topographic maps were published during the year, and one is in press.

REPORTS ISSUED.

Bulletin 630. The Chisana-White River district, Alaska, by S. R. Capps; including geologic and topographic reconnaissance maps.

Bulletin 631. The Yukon-Koyukuk region, Alaska, by H. M. Eakin; including geologic and topographic reconnaissance maps.

Bulletin 642. Mineral resources of Alaska: Report on progress of investigations in 1915, by A. H. Brooks and others; including new edition of map showing distribution of mineral resources in Alaska.

Bulletin 649. The antimony deposits of Alaska, by A. H. Brooks.

Water-Supply Paper 372. A water-power reconnaissance in south-central Alaska, by C. E. Ellsworth and R. W. Davenport.

REPORTS IN PRESS.

Bulletin 657. The use of the panoramic camera in topographic surveying, with notes on the application of photogrammetry to aerial surveys, by J. W. Bagley. (Published Apr. 20, 1917.)

Bulletin 655. The Lake Clark-Central Kuskokwim region, by P. S. Smith.

Water-Supply Paper 418. The mineral springs of Alaska, by G. A. Waring.

REPORTS FOR WHICH ILLUSTRATIONS ARE BEING PREPARED.

The Canning River region of northern Alaska, by E. de K. Leffingwell.

The Nelchina-Susitna region, by Theodore Chapin.

The Cosna-Nowitna region, by Theodore Chapin.

The upper Chitina Valley, by F. H. Moffit.

REPORTS IN PREPARATION.

The marble resources of southeastern Alaska, by E. F. Burchard.

The lower Kuskokwim region, by A. G. Maddren.

The Kotsina-Kuskulana district, by F. H. Moffit.

The upper Matanuska basin, by G. C. Martin.

Geology of the Glacier Bay and Lituya region, Alaska, by F. E. Wright and C. W. Wright.

Geology of the region along the international boundary from Porcupine River to the Arctic Ocean, by A. G. Maddren.

TOPOGRAPHIC MAPS ISSUED.

Reconnaissance map of Yukon-Koyukuk region and adjacent territory, by H. M. Eakin, D. C. Witherspoon, and R. B. Oliver; scale, 1:500,000; contour interval, 400 feet. (Plate I, Bulletin 631.)

Reconnaissance map of Chisana-White River district, by C. E. Giffin; scale, 1:250,000; contour interval, 200 feet. (Plate I, Bulletin 630.)

TOPOGRAPHIC MAPS IN PRESS.

Lower Matanuska Valley, by R. H. Sargent; scale, 1:62,500; contour interval, 50 feet. Sale edition.

THE ALASKAN MINING INDUSTRY IN 1916.

By ALFRED H. BROOKS.

GENERAL FEATURES.

In 1916 Alaska mines yielded a mineral output valued at $48,632,138. The output in 1915, which was greater than that of any previous year, had a value of $32,854,229, and therefore the increase in 1916 was over $15,700,000, or nearly 50 per cent. Although this enormous increase was due in great part to the large tonnage and high price of copper, yet nearly all other minerals were produced in greater quantities than in the previous year.

It can not be expected that Alaska will continue to produce so much mineral wealth each year, yet the large amount of preparation made in 1916 for lode and placer mining and the development of the coal-mining industry, now assured, give promise of a continuous healthy growth to the mining industry of the Territory. This is especially true of the Pacific coast region and of the territory served by railroads built or under construction.

The principal facts relating to Alaska's annual production are graphically presented on Plate II (p. 12). This shows that the small beginning of Alaska's great mining industry was made in 1880,[1] when about $20,000 worth of gold was won from the Juneau placers. During 37 years of mining the value of the annual mineral output has grown to nearly $50,000,000. This growth has not been uniform, especially after 1898, when the yield of gold from the placers became a large element in the value of the total annual mineral output. For many years the fluctuation in total annual value was a reflection of the condition of the placer-mining industry. Since 1910 the variation in value of the copper output has also been an important element in determining the curve of mineral production.

Some silver has always been recovered incidentally to the mining of Alaskan gold. During the last 20 years tin, copper, marble, gypsum, and other mineral products have helped to swell the value of the mineral output. Up to 1898 the value of the mineral production other than that of the gold is so small that it can not be shown on the scale of the accompanying diagram (Pl. II).

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[1] A little placer mining was done in the Sumdum and Windham bays region between 1875 and 1880, but there is no reliable record of the amount of gold produced.

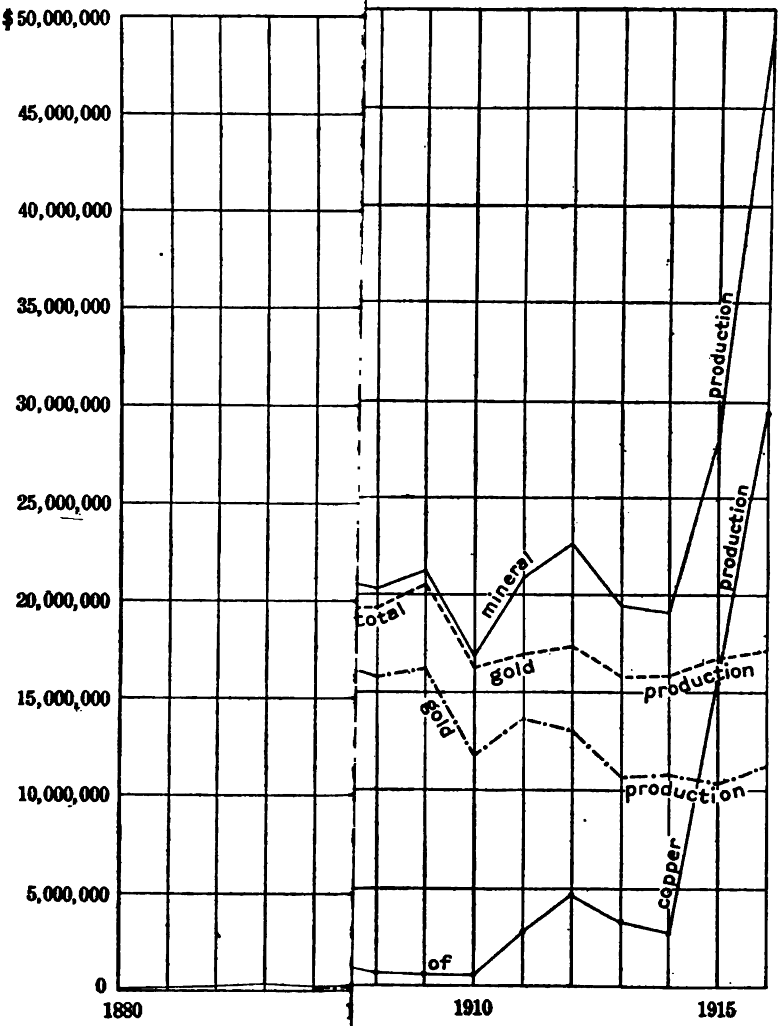
Though it is generally assumed that the annual gold output of the Territory has been derived largely from placer mines, this is not entirely true. From the time that lode mining began in 1883 until the discovery of the rich placers of Nome in 1898 the value of the gold output from the lodes was greater than that of the placers. Throughout this period the total annual gold production of Alaska was steadied by the output of the great Treadwell group of mines. It is for this reason that the curve of mineral production (Pl. II) shows but few fluctuations during the first 20 years of mining.

With the discovery of the Nome gold field in 1898 the Alaskan mining industry passed into a second phase of its evolution. In this epoch the output of the placers played a dominating part in the value of the annual production, which fluctuated greatly from year to year. The first peak in mineral production was reached in 1900 and was due to the gold from Seward Peninsula. A second was reached in 1906, when a large production from the Fairbanks placer mines was added to that of Seward Peninsula. Had it not been for the rapid successive discovery of such camps as Nome, Fairbanks, Iditarod, Hot Springs, Ruby, and others, the gold output would not have been maintained. The development of a new camp at about the time of the decline of the output from an older camp prevented much greater fluctuation in the annual product than actually took place. This period was an era both of wasteful mining and excessive speculation. Placer mining was regarded more as a gamble than as a legitimate business. Many rich claims were gutted without thought of the future. Few operators looked forward to the day when the bonanzas would be worked out and a continuation of the placer-mining industry would depend on the exploitation of larger bodies of gravel with a gold content too low to be profitably handled by the crude methods then in general use.

From this epoch of bonanza placer mining Alaska is gradually emerging, the first step being the installation of large dredges on Seward Peninsula, which began in 1905. Since then many others have been installed on the peninsula, and dredge mining is becoming an important industry in other parts of the Territory. There has also been a general improvement in placer-mining methods in all of the older placer districts and a consequent steadying of the annual production. As a result, the curve of Alaska's annual placer gold production has shown comparatively little variation during the last four years. The maintenance of a large annual output of placer gold seems assured, though it does not necessarily follow that the minimum output has been reached. There is still a large percentage of gold won from bonanza deposits which have no great extent. Until the annual gold placer production is derived largely from the exploitation

U. S. GEOLOGICAL SURVEY

BULLETIN 662 PLATE II



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a large scale of extensive deposits, fluctuations in annual output are
be expected.

The annual fluctuation in value of Alaska's copper output reflects
variation in the price of copper. This acts directly, in deter-
ining the value of the copper actually produced, and indirectly
ause when copper is high a number of mines are operated that are
during periods of low price. The abnormally high price of copper
ing the last two years accounts in large measure for the very high
ard grade of the curve of copper production (Pl. II) as well as of
curve of total mineral production. There is no question, how-
r, that though this curve is abnormal and can not be taken as a
sure of future value, yet there is every assurance that Alaska will
tinue to make a large annual copper output, even under normal
ket conditions.

There was an increase in 1916, compared with the previous year, of
output from both the Alaskan placer and lode gold mines. In
te of the curtailment of stibnite mining when the price of anti-
ny dropped in midsummer, a larger quantity was mined in 1916
n in 1915. For the first time in its history Alaska produced
gsten, scheelite ores having been mined in the Fairbanks and
me districts during 1916. The tin production was about the same
n the previous year. There was some increase of lead production,
for the first time a small output of platinum from Alaskan mines.

The completion of the Government railroad to the lower end of the
tanuska coal field (see Pl. I, in pocket) encouraged the opening of
small mines, which produced some bituminous coal for local use.
ittle bituminous coal was also mined at the southwest end of the
ing River field. There was an increased output of lignitic coals
pared with previous years from several small mines. Steps were
en to develop bituminous coal mines on a larger scale, and these
elopments, together with the receipt by the Interior Department
pplications for leases in both the Bering River and Matanuska
l fields, give assurance of the beginnings of an Alaskan coal-mining
ustry. The production of coal in Alaska will stimulate all other
nches of mining. As the Alaskan oil lands are withdrawn from
ry and no provision has been made for leasing them, no large
elopment of Alaskan petroleum has taken place. The only
roleum company operating in Alaska, in the Katalla field, increased
development work in 1916, compared with 1915.

In addition to the minerals mentioned above, marble and gypsum
re produced on about the same scale as in previous years. Devel-
ment work was done on deposits of molybdenite, chromic iron ore,
d graphite. Some graphite was mined on Seward Peninsula but
s not shipped.

The statistics for Alaska's mineral production in 1915 and 1916 are given in the subjoined table. The output of marble, gypsum, petroleum, etc., is given as a single item, because a separate listing might reveal the production of individual properties.

Mineral output of Alaska, 1915 and 1916.

	1915		1916		Increase in 1916.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Gold..........fine ounces..	807,966	$16,702,144	834.067.87	$17,241.713	26,101.87	$539,569
Silver..............do....	1.071,782	543.393	1,379,261	907.554	307,479	364,161
Copper............pounds..	86,509,312	15,139,129	119,602,028	29,484,291	33,092,716	14,345,162
Tin, metallic..........tons..	102	78,846	139	121,000	37	42,154
Antimony, crude ore....do....	833	74,000	1,458	131,000	625	60,000
Lead...........short tons..	437	41,118	820	109,120	383	68,002
Coal..................do....	1,400	3,300	12,200	55,000	10,800	51,700
Marble, gypsum, petroleum, platinum, tungsten, etc.....	....	[a] 272,299	....	579,500	....	307,201
Total..................	....	32,854,229	....	48,632,178	....	15,777,949

[a] No platinum or tungsten included.

Productive mining began in Alaska in 1880, when the Juneau gold placers were first exploited. It is estimated that since that time mineral wealth has been produced to the value of nearly $350,000,000. This output, by years and substances, is summarized in the following table: ·

Value of total mineral production of Alaska, 1880–1916.

By years.				By substances.	
1880–1890.............	$4,686,714	1904.................	$9,569,715	Gold	$278,100,656
1891.................	916,920	1905.................	16,480,762	Silver	3,729,465
1892.................	1,098,400	1906.................	23,378,428	Copper	64,403,872
1893.................	1,051,610	1907.................	20,850,235	Tin	579,852
1894.................	1,312,567	1908.................	20,145,632	Antimony	208,000
1895.................	2,388,042	1909.................	21,146,953	Lead	217,380
1896.................	2,981,877	1910.................	16,887,244	Coal	420,833
1897.................	2,540,401	1911.................	20,691,241		
1898.................	2,587,815	1912.................	22,536,849	Marble, gypsum, petroleum, etc.......	1,925,871
1899.................	5,706,226	1913.................	19,476,356		
1900.................	8,241,734	1914.................	19,065,666		349,585,929
1901.................	7,010,838	1915.................	32,854,229		
1902.................	8,403,153	1916.................	48,632,178		
1903.................	8,944,134				
			349,585,929		

GOLD, SILVER, AND COPPER.

The following table gives an estimate of the total production of gold, silver, and copper since the beginning of mining in 1880. For the earlier years, especially for silver, the figures are probably far from being correct. but they are based on the best information now available.

Production of gold, silver, and copper in Alaska, 1880–1916.

Year.	Gold.		Silver.		Copper.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Commercial value.	Quantity (pounds).	Value.
1880	967	$20,000	10,320	$11,146	3,933	$826
1881	1,935	40,000			....	....
1882	7,256	150,000			....	....
1883	14,561	301,000			....	....
1884	9,724	201,000			....	....
1885	14,512	300,000			....	....
1886	21,575	446,000			....	....
1887	32,653	675,000			....	....
1888	41,119	850,000	2,320	2,181	....	....
1889	43,538	900,000	8,000	7,490	....	....
1890	36,862	762,000	7,500	6,071	....	....
1891	43,538	900,000	8,000	7,920	....	....
1892	52,245	1,080,000	8,000	7,000	....	....
1893	50,213	1,038,000	8,400	6,570	....	....
1894	62,017	1,282,000	22,261	14,257	....	....
1895	112,642	2,328,500	67,200	44,222	....	....
1896	138,401	2,861,000	145,300	99,087	....	....
1897	118,011	2,439,500	116,400	70,741	....	....
1898	121,760	2,517,000	92,400	54,575	....	....
1899	270,997	5,602,000	140,100	84,276	....	....
1900	395,030	8,166,000	73,300	45,494	....	....
1901	335,369	6,932,700	47,900	28,598	250,000	40,000
1902	400,709	8,283,400	92,000	48,590	360,000	41,400
1903	420,069	8,683,600	143,600	77,843	1,200,000	156,000
1904	443,115	9,160,000	198,700	114,934	2,043,586	275,676
1905	756,101	15,630,000	132,174	80,165	4,805,236	749,617
1906	1,066,030	22,036,794	203,500	136,345	5,871,811	1,133,260
1907	936,043	19,349,743	149,784	98,857	6,308,786	1,261,757
1908	933,290	19,292,818	135,672	71,906	4,585,362	605,267
1909	987,417	20,411,716	147,950	76,934	4,124,705	536,211
1910	780,131	16,126,749	157,850	85,239	4,241,689	538,695
1911	815,276	16,853,256	460,231	243,923	27,267,878	3,408,485
1912	829,436	17,145,951	515,186	316,839	29,230,491	4,823,031
1913	755,947	15,626,813	362,563	218,988	21,659,958	3,357,293
1914	762,596	15,764,259	394,805	218,327	21,450,628	2,852,934
1915	807,966	16,702,144	1,071,782	543,393	86,509,312	15,139,129
1916	834,068	17,241,713	1,379,171	907,554	119,602,028	29,484,291
	13,453,119	278,100,656	6,302,459	3,729,465	339,515,403	64,403,872

The subjoined table gives an estimate, based on the best available data, of the source of the gold and silver produced in Alaska since mining began in 1880. About $65,100,000 worth of gold, or nearly one-third of the total estimated output, was produced before 1905, and there is but scant information about its source. For the period since that time fairly complete statistical returns are available, and it is probable that the figures presented in the following table are near enough to the truth to be valuable. The figures given for the silver recovered from placer gold and from siliceous ores are probably less accurate than those for the gold. Copper mining did not begin in Alaska until 1901, and the figures for gold and silver derived from this industry, as now presented, are therefore a close approximation to the actual output.

Estimate of sources of gold and silver produced in Alaska, 1880–1916.

	Gold.		Silver.	
	Quantity.	Value.	Quantity.	Value.
	Fine ounces.		*Fine ounces.*	
Siliceous ores	3,844,404	$79,470,900	1,096,238	$731,256
Copper ores	62,731	1,296,764	3,567,308	2,089,519
Placers	9,545,984	197,332,992	1,638,913	908,690
	13,453,119	278,100,656	6,302,459	3,729,465

The above table shows that about 28 per cent of the total gold production of Alaska has been obtained from the auriferous lode mines (siliceous ores). In 1916 the lode-gold production was 38 per cent; in 1915, 37 per cent; in 1914, 32 per cent; in 1913, 31.6 per cent; and in 1912, 29 per cent. In the following table the production of precious metals has been distributed as to sources:

Sources of gold, silver, and copper produced in Alaska, 1916.

	Total quantity.	Gold.		Silver.		Copper.	
		Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	*Fine ounces.*		*Fine ounces.*		*Pounds.*	
Siliceous ores	3,448,798	286,028.60	$5,912,736	110,050	$72,413	....	....
Copper ores	617,264	9,141.77	188,977	1,207,121	794,286	119,602,028	$29,484,291
Placers	....	538,897.50	11,140,000	62,090	40,855	....	....
	4,066,062	834,067.87	17,241,713	1,379,261	907,554	119,602,028	29,484,291

The enormous copper output from Alaskan mines in 1916—a total of 119,602,028 pounds, valued at $29,484,291—has already been mentioned. During the year 18 copper mines were operated, compared with 13 in 1915—nine in the Ketchikan district, six in the Prince William Sound district, and three in the Chitina district. The great output from the Kennecott and Jumbo mines, in the Chitina district, overshadowed all other operations. Had the transportation companies and smelters been able to handle the ore, however, many of the smaller copper mines on the coast would have made a much greater output. The average copper content of the ores mined was 9.7 per cent, and the value of gold and silver recovered about $1.60 to the ton. The average for 1915 was 11.7 per cent copper and $1.65 to the ton in gold and silver.

Twenty-nine gold-lode mines, large and small, were operated in 1916—one less than in 1915. The value of the lode-gold output decreased from $6,069,023 in 1915 to $5,912,736 in 1916. Southeastern Alaska, especially the Juneau district, is still the only center of large quartz-mining developments in the Territory. Next in importance is the Willow Creek lode district. There was also considerable gold-lode mining on Prince William Sound, but a very decided falling off of this industry in the Fairbanks district. Lode-mine owners of Fairbanks are awaiting the cheapening of operating costs, especially of fuel, which will be brought about by the Government railroad. Of the producing mines eight were in southeastern Alaska, five on Prince William Sound, four on Kenai Peninsula, four in the Willow Creek district, and eight in the Fairbanks district. In 1916 the average value of the gold and silver contents for all siliceous ores mined was $1.70 a ton; the average for 1915 was $2.79 a ton. These averages reflect the dominance in the total lode production of the large tonnage produced from the low-grade ores of the Juneau district.

In 1915 about 4,400 men were employed in the Alaskan lode-mining industry. Accurate figures on the number employed in 1916 are not available at this writing, but it probably was at least 5,000.

The value of the placer gold produced in 1916 was about $11,140,000; in 1915 it was $10,480,000. All the older placer districts, except Fairbanks, have maintained or increased their gold output compared with the previous year. The increased output is, however, to be credited chiefly to the newly developed Marshall and Tolovana districts. It is estimated that about 650 placer mines were operated in the summer of 1916 and 215 during the previous winter, but many for only a part of the season. About 4,050 men were engaged in productive placer mining in the summer and 880 in the winter. In addition, probably 1,000 men were engaged in prospecting or other nonproductive work relating to placer mining. The only new placer-bearing area discovered during 1916 was in the Tolstoi Creek basin, in the southern part of the Innoko district, and here but little productive mining was done. There were, however, notable developments of gold placers in the Marshall and Tolovana districts and in the Dime Creek region of the southeastern part of Seward Peninsula.

In accordance with past practice, a table is given here to show approximately the total bulk of gravel mined annually and the value of the gold recovered per cubic yard. The table is based in part on returns made by placer-mine operators and in part on certain assumptions which do not now admit of proof but which are supported by a large number of facts. Therefore, although the table is only approximately correct, it indicates the order of magnitude of the true figures.

Estimated amount of gravel sluiced in Alaskan placer mines and value of gold recovered, 1908–1916.

Year.	Total quantity of gravel.	Value of gold recovered per cubic yard.	Year.	Total quantity of gravel.	Value of gold recovered per cubic yard.
	Cubic yards.			*Cubic yards.*	
1908	4,275,000	$3.74	1913	6,800,000	$1.57
1909	4,418,000	3.66	1914	8,500,000	1.26
1910	4,036,000	2.97	1915	8,100,000	1.29
1911	5,790,000	2.17	1916	7,100,000	1.57
1912	7,050,000	1.70			

The above table shows that during the last nine years there has been a decline in the average gold content of the gravels mined. This is a reflection of the improved methods of placer mining that are being introduced, especially in the use of dredges. If data were available on the average gold recovery previous to 1908 a far greater decline would be noted. The rise of the average recovery in 1916 compared with 1915 is due largely to the fact that the Alaskan dredges were for the most part working on far richer placers. This change is also influenced by the fact that in 1916, as compared with 1915, a larger percentage of the placer gold came from the rich deposits of newer districts, such as Hot Springs, Tolovana, and Koyukuk. In these districts gold recoveries of $7 to $20 a cubic yard are not uncommon. In the final analysis the movement of the miners toward the richer placers, made evident by the average recoveries for 1915 and 1916, is the result of the present economic conditions, which, as will be shown below, affect gold mining more adversely than any other industry.

Thirty-four gold dredges were operated in Alaska in 1916, one less than in 1915. The dredging companies employed about 440 men. Four dredges were built during the year. Twenty-seven dredges were in Seward Peninsula, three in the Iditarod, and one each in the Ruby, Fairbanks, Circle, and Yentna districts. These dredges produced about $2,679,000 worth of gold and handled about 3,900,000 cubic yards of gravel. In 1915 the 35 dredges handled about 4,600,000 cubic yards of gravel and made a gold recovery worth $2,330,000. The average gold recovery per cubic yard was about 69 cents in 1916 and 51 cents in 1915. The gold dredges of Seward Peninsula made an average recovery of 53 cents a cubic yard in 1916 and 35 cents in 1915. The dredges of the Alaska Yukon districts are working on placers of relatively high gold tenor. The value of gold recovery per cubic yard in 1916 was about 85 cents; in 1915, about 80 cents.

The above statements do not encourage the hope of an immediate expansion of the dredging industry of Alaska. During the last three years there has been a decrease in the number of dredges operated, and the gold output from this source has been maintained by the production of a few machines working on relatively rich placers. Dredging companies in Seward Peninsula, which have in the past mined gravels of lesser gold tenor, have in part ceased operations, and there is now a general tendency throughout Alaska to limit the installation of dredges to relatively rich placers. This is no doubt due in large part to present economic conditions, by which the gold-mining industry suffers most, for the value of the product is relatively less than under normal conditions, and yet, as in other industries, the cost of operation is increased by high prices.

There are in Alaska many placers rich enough to be dredged under present adverse conditions, and the exploitation of these placers will continue more extensively than in the past. The best hope for a permanent dredging industry, however, is in the mining of the large bodies of auriferous gravels whose gold tenor is too low to be attractive to operators under present economic conditions.

Though dredges were built for use in the Alaska Yukon as early as 1898 and at Nome in 1900, this method of placer mining did not reach a profitable stage until 1903, when two small dredges were successfully operated in Seward Peninsula. Dredging began in the Fortymile district in 1907; in the Iditarod, Birch Creek, and Fairbanks districts in 1912, and in the Yentna district in 1916. Up to the end of 1916 gold to the value of $15,110,000 has been mined by dredges. The distribution of this output by years is shown in the following table:

Estimate of gold produced from dredge mining in Alaska, 1903–1916.

Year.	Number of dredges operated.	Value of gold output.	Year.	Number of dredges operated.	Value of gold output.
1903	2	$20,000	1911	27	$1,500,000
1904	3	25,000	1912	38	2,200,000
1905	3	40,000	1913	36	2,200,000
1906	3	120,000	1914	42	2,350,000
1907	4	250,000	1915	35	2,330,000
1908	4	171,000	1916	34	2,679,000
1909	14	425,000			
1910	18	800,000			15,110,000

TIN.

The Alaskan mines produced 139 tons of metallic tin, valued at $121,000, in 1916, compared with 102 tons, valued at $78,846, in 1915. Most of this tin came from the York district, in Seward Peninsula, where four dredges were operated in 1916, of which two were working on gravels carrying gold as well as tin. Considerable development work was done on the tin lodes of the York district, notably at the Lost River mine. As in the past, much stream tin was recovered from the gold placer mines of the Hot Springs district. The following table shows the Alaskan tin production by years:

Tin produced in Alaska, 1902–1916.

Year.	Quantity (tons of metallic tin).	Value.	Year.	Quantity (tons of metallic tin).	Value.
1902	15	$8,000	1911	61	$52,798
1903	25	14,000	1912	130	96,000
1904	14	8,000	1913	69	44,103
1905	6	4,000	1914	104	66,560
1906	34	38,640	1915	102	78,846
1907	22	16,752	1916	139	121,000
1908	25	15,180			
1909	11	7,638		767	579,852
1910	10	8,335			

LEAD.

Though silver-lead ores are found in many parts of Alaska no deposits of them have yet been opened on a commercial basis. The lead production is therefore still only incidental to the mining of ores chiefly valuable for other metals. Some test shipments of galena ore were made from several deposits in 1916, and these, with the much larger recovery of lead from gold ores, made a total output of 820 tons of lead, valued at $109,120, compared with a production in 1915 of 437 tons, valued at $41,118. The following table shows the lead production of Alaska, so far as it can be determined from available data:

Estimate of lead produced in Alaska, 1892–1916.

Year.	Quantity (tons).	Value.	Year.	Quantity (tons).	Value.
1892	30	$2,400	1906	30	$3,420
1893	40	3,040	1907	30	3,180
1894	35	2,310	1908	40	3,360
1895	20	1,320	1909	69	5,934
1896	30	1,800	1910	75	6,600
1897	30	2,160	1911	51	4,590
1898	30	2,240	1912	45	4,050
1899	35	3,150	1913	6	528
1900	40	3,440	1914	28	1,344
1901	40	3,440	1915	437	41,118
1902	30	2,460	1916	820	109,120
1903	30	2,520			
1904	30	2,580		2,081	218,724
1905	30	2,620			

ANTIMONY.

The mining of antimony ore (stibnite) began in Alaska in 1915 and was continued on about the same scale throughout the first half of 1916. The drop in the price of antimony during midsummer put an end to most of these operations. About 1,458 short tons of crude ore, valued at $134,000, was mined in 1916. The output in 1915 was 833 tons, valued at $74,000. Most of this antimony ore came from two mines in the Fairbanks district, where two other mines also made a small production. Stibnite ore was also produced from ore mined in the Nome district, but no shipments were made. A more detailed account of antimony mining at Fairbanks and Nome will be found in another section of this report.

TUNGSTEN.

Though scheelite has long been known to occur in some of the Alaskan placers, until the last two years the demand for it has not been sufficient to encourage its recovery. The recent high price of tungsten has induced Alaskan miners to turn their attention to scheelite deposits. In the fall of 1915 a scheelite-bearing vein was discovered in the Fairbanks district, and its development began. Later two other scheelite-bearing veins were found in the same district. During the winter some of these scheelite ores were treated in a local mill and the concentrates were shipped out by parcel post. Scheelite mining was continued during the summer, and the crude ore was shipped out by steamer. Considerable scheelite was also recovered from some of the gold placers at Nome, and a little was produced in other districts. It is estimated that about 47 tons of scheelite concentrates, including a little wolframite, were produced in Alaska during 1916, for which the producers received about $109,300. A more detailed description of tungsten mining in Alaska is given elsewhere in this report.

PLATINUM.

Platinum has been reported in association with gold placers at many widely separated localities in Alaska. Some of the reported occurrences after investigation have proved not to contain platinum; at others small quantities of the metal have been found in concentrates from placer-mining operations. Traces of platinum have also been found in a copper-bearing lode in the Ketchikan district.

In 1916 the value of the crude platinum recovered from placer mines of the west coast was from $60 to $70 an ounce. This high price both stimulated the search for platinum deposits and led mine operators to examine their concentrates for platinum. Complete returns on platinum production are lacking, but the evidence in hand indicates that between 10 and 12 ounces was recovered from Alaska placers in 1916. This came from Dime Creek, in the Koyuk district of Seward Peninsula; from Bear Creek, in the Fairhaven district of Seward Peninsula; and from Slate Creek, in the Chistochina district of the upper Copper River basin. In view of the present great demand for platinum it seems desirable to summarize the rather scant data relating to Alaskan platinum deposits. The localities where platinum is known to occur will be described and also those where it has been reported, even though the report has not yet been verified.

Traces of platinum and palladium have recently been found in association with the copper ores of the Goodro mine, on Prince of Wales Island in the Ketchikan district. This copper-bearing lode has been described by Knopf[1] as "a heavy green dioritic rock, containing much biotite and, as the main copper-bearing mineral, scattered particles of bornite, with which are associated sporadic blebs of chalcocite and chalcopyrite." Wright,[2] who has mapped the geology of the Goodro deposits, describes the country rock as a gabbro, a marginal phase of the diorite widely distributed in the district. In regard to the distribution of the Goodro type of copper deposits, Wright[3] says: "Irregular disseminated bodies of copper ore occur in an intrusive belt of gabbro that extends along the northeast side of the salt chuck at the head of Kasaan Bay, extending northwestward and averaging about a mile in width. Copper ore has been found at only a few places in this intrusive belt and has been mined only at the Goodro mine." In other words, the geologic conditions existing at the Goodro mine are probably repeated at other localities. If the Goodro ore proves to carry platinum in commercial quantity an examination of deposits of similar types for platinum is justified.

No platinum has been found in any other lode deposits of Alaska. Some very basic intrusive rocks (peridotite) of the general type with which platinum deposits occur are present in the southern part of Kenai Peninsula, but so far as known these have not been examined for platinum. Chromite ore occurs in association with some of these intrusives, deposits having been found at Red Mountain,[4] 7 miles from Seldovia, and near Port Chatham. It is not intended to imply that these deposits carry any platinum, but only that their geology is such as to justify their examination for this metal. However, chromite-bearing veins have also been found near Ruth Creek, in the Tolovana district, and the gold placers of this district carry chromite but no platinum.

A little platinum has been won from the Slate Creek placers of the Chistochina district, in the Copper River basin. It has long been known that a little osmium and iridium occur in the placers of Miller Gulch, also in the Chistochina district.[5] Many years ago it was reported that platinum occurred in the gravels of Nadina River, also in the Copper River basin. A careful study of these deposits by Mendenhall[6] failed to reveal any platinum.

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[1] Knopf, Adolph, Mining in southeastern Alaska: U. S. Geol. Survey Bull. 442, p. 141, 1910.

[2] Wright, C. W., Geology and ore deposits of Copper Mountain and Kasaan Peninsula, Alaska: U. S. Geol. Survey Prof. Paper 87, pp. 75, 86, 87, 99, 1915.

[3] Idem, p. 86.

[4] Martin, G. C., Johnson, B. L., and Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, pp. 237-238, 1915.

[5] Mendenhall, W. C., Geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, p. 123, 1905.

[6] Idem, pp. 121-122.

Many of the beach placers of the Pacific coast belt have been reported to carry platinum. It seems pretty definitely established that at least small quantities of platinum occur in the beach placers of Lituya Bay. It was long ago reported that a little platinum occurred in the beach placers of Yakutat Bay. This report has not been confirmed, for an examination of the auriferous beach sands from the north end of Khantaak Island[1] failed to reveal the presence of platinum. No platinum has been found in the beach placers of Yakataga.[2] Platinum has been reported to occur in some of the beach placers of Kodiak Island. The only sample tested from this region was taken from the "7-mile beach" near Uyak, and this revealed no trace of platinum. A little platinum is said to occur in the beach placers near the mouth of Red River, Kodiak Island.

The presence of platinum has been reported in the gold placers of Colorado Creek, on Kenai Peninsula, also on Kahiltna River, in the Yentna district. No samples from these localities have been examined by the Survey, but the writer is indebted to Prof. Herschel C. Parker for the information that as the result of drilling of auriferous gravels in the Kahiltna River valley in the search for dredging ground, considerable alluvial platinum was found, including some nuggets the size of the head of a match. Basic intrusive rocks of the type with which platinum is sometimes found associated occur in the Alaska Range,[3] in which Kahiltna River has its source. No other occurrence of platinum has been reported from the Yentna district, but the amount found in the Kahiltna River gravels justifies a further search for it. Its occurrence in the river gravels suggests that it may be more abundant in the gravels of some of the tributary streams.

Many years ago a trace of platinum was obtained from some concentrates procured by placer mining in the Fortymile district. The exact locality of this specimen is unknown. As only a very few grains of platinum were obtained, this information has no direct commercial value. It is desirable, however, for the placer operators in the Fortymile district to have the concentrates from mining examined for platinum.

A specimen sent to the Geological Survey by J. S. Pitcher and reported to be concentrates from placer mining on Boob Creek, in the Innoko district, was found to contain some platinum and palladium. Boob Creek, the scene of new placer-mining developments in 1916, flows into Mastodon Creek, which is tributary to Tolstoi Creek, an easterly confluent of Innoko River. Little is known of the local geology, and nothing of the extent of the deposit in which the platinum was found. In the general region there is known to be an older series made up of limestones, with some greenstones, and a younger Mesozoic succession of conglomerate, sandstone, and shale. The Mesozoic rocks are intruded by granite and diorite rocks with some pyroxenite.[1] It is probable that the placer platinum is derived from bedrock deposits associated with the pyroxenite, which is a dark-green, very heavy igneous rock.

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[1] Brown, J. S., Report on auriferous sands from Yakutat Bay: Nat. Geog. Mag., vol. 3, pp. 196–198, 1891.

[2] Maddren, A. G., Mineral deposits of the Yakataga district: U. S. Geol. Survey Bull. 592, p. 137, 1914.

[3] Brooks, A. H., The Mount McKinley region: U. S. Geol. Survey Prof. Paper 70, pp. 104, 147–148, 1911.

One of the most promising finds of platinum reported in Alaska is on Dime Creek, in the Koyuk district of the southeastern part of Seward Peninsula. A little gold mining was done on Dime Creek in 1915, and seven or eight plants were operated in 1916. Incidentally to this gold output several ounces of platinum was recovered, and this without any attempt to seek out deposits valuable for platinum. According to the report of prospectors the platinum appears to have been derived from an area of greenstones. These greenstones are probably the altered intrusive rocks in Paleozoic sediments described by Smith and Eakin.[2] No examination has been made of this platinum occurrence by the Survey, but the facts stated indicate that the metal may be present in sufficiently large quantities to warrant its systematic recovery. Platinum has also been found in the placers of Bear Creek, in the Fairhaven district, which includes the northeastern part of Seward Peninsula. No details regarding this occurrence are known. Most of the Bear Creek drainage basin lies in a region of volcanic and intrusive rocks.[3]

The facts above given indicate that at several widely separated localities in Alaska the gold placers carry sufficient platinum to justify special search for it. Some of these placers may even prove to be of greater value for their platinum than for their gold content. In any event, the placer miners should carefully examine the concentrates from their operations. The Geological Survey will be glad to make qualitative tests for platinum of concentrates submitted for that purpose. In districts where extensive placer mining has been carried on the presence of any considerable platinum in the concentrates is not likely to be overlooked. Its presence may, however, be known to the purchaser of the gold and not to the miner. It is also possible that platinum occurs where there is little or no gold. Therefore the prospector will do well to examine all his concentrates for platinum, even if no gold is present. So far as known, the most likely place for platinum is in regions of very basic igneous rocks. These can be recognized by their dark-green color and their great weight. They are heavier than the ordinary diorite or granite so common in Alaska. Some of them are coarsely crystalline; others are fine grained. In places they are altered to serpentine, a light-green fibrous rock.

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[1] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, pl. 3, 1914. Mertie, J. B., Mineral resources of the Ruby-Kuskokwim region: U. S. Geol. Survey Bull. 642, p. 251, 1916, and unpublished notes.

[2] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, pp. 61-64, 1911.

[3] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 247, pp. 63-64, 1905.

MISCELLANEOUS METALLIFEROUS DEPOSITS.

Some prospecting was done during 1916 on the chromite deposits near Seldovia and Port Chatham, in the southwestern part of Kenai Peninsula. A chromite-bearing vein was found by J. B. Mertie in the Tolovana placer district and is described by him in another section of this volume. No direct report has been received about the quicksilver deposits of the lower Kuskokwim basin.[1] It is known, however, that developments were continued at the Parks mine and that several other quicksilver deposits were prospected.

Some work was done on a molybdenite deposit on the White Pass Railroad, about 25 miles from Skagway. The owners report that the developments consist of a 10-foot shaft and a 25-foot adit and that the deposit occurs in a broad zone of mineralization in a country rock of granite. Molybdenite has also been found on Canyon Creek, a northerly tributary of the Chitina, about 50 miles from the Copper River Railroad at McCarthy,[2] and on Lemesurier Island, in Icy Strait.[3] So far as known no developments were made on these two deposits during 1916. A copper-bearing lode, which is reported to carry nickel and a little cobalt, has been discovered and developed near Pinta Cove, on the west side of Chichagof Island. The Survey has received a specimen of nickel-bearing ore which is said to be from a lode near Spirit Mountain, in the lower Copper River region.

COAL MINING.

In 1916 about 12,200 net tons of coal, valued at $55,000, was mined in Alaska; in 1915 the output was 1,400 tons, valued at $3,300. Most of the coal mined in 1916 came from the Doherty mine, in the Matanuska field; from the Bluff Point mine, on Cook Inlet; and from the Short Creek mine, in the Yentna district. Some coal was also taken from the La Duke mine, in the Matanuska field, and from the McDonald mine, in the Bering River field. (See Pl. I, in pocket.) A little coal was mined on Chicago Creek, in Seward Peninsula, and one small shipment of coal was made to Nome from the Corwin mine, in the Cape Lisburne field.

The most important event of the year to the Alaskan coal industry was the opening of the Bering River and Matanuska fields for leasing under the new law. These two fields were subdivided into leasing units by the Bureau of Mines in 1915. In 1916 the Geological Survey made a detailed geologic survey of the western part of the Nenana coal field, thus acquiring the information necessary for subdividing this field into leasing units. The Interior Department has received a number of applications for leases in both the Matanuska and Bering River fields. The lower end of the Matanuska field was reached by the Government railroad in the summer of 1916, and an extension of the line into the heart of the field is now being built. It is also hoped that the Nenana field may be made accessible by railroad at an early date. This will make it possible to supply Fairbanks and other Yukon camps with the cheap fuel urgently needed by the gold mining industry. The small amount of coal produced at the McDonald mine, on Bering Lake, in the Bering River field, was sold in a local market. A survey was made and some construction work done on a railroad to be built from Goose Point, on Bering River, to Canyon Creek, in the Bering River field. Goose Point is accessible to barges from Controller Bay by way of the lower reaches of Bering River, which is a tidal estuary. This railroad will be about 17 miles in length and is intended for coal traffic.

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[1] For information regarding these deposits, see Smith, P. S., and Maddren, A. G., Quicksilver deposits of the Kuskokwim region: U. S. Geol. Survey Bull. 622, pp. 272-291, 1915.

[2] Brooks, A. H., The Alaskan mining industry in 1915: U. S. Geol. Survey Bull. 642, p. 54, 1916.

[3] Knopf, Adolph, The Sitka mining district, Alaska: U. S. Geol. Survey Bull. 504, p. 17, 1912.

The subjoined table shows the coal consumption of Alaska, including both imports and local production, since 1899. Most of the coal used up to 1916 was lignite. There was in 1906 a small production of bituminous coal from the seaward end of the Bering River field. The table does not include 855 tons of coal mined in the Bering River field in 1912 and 1,100 tons mined in the Matanuska field in 1913 for test by the United States Navy. Most of the coal shipped to Alaska is bituminous, but a little is anthracite.

Coal consumed in Alaska, 1899 to 1916, in short tons.

Year.	Imported from States, chiefly bituminous from Washington.	Produced in Alaska, chiefly subbituminous and lignite.	Total domestic, chiefly from Washington.	Total foreign coal, chiefly bituminous from British Columbia.[a]	Total coal consumed.
1899	10,000	1,200	11,200	50,120	61,320
1900	15,048	1,200	16,248	56,623	72,871
1901	24,000	1,300	25,300	77,674	102,974
1902	40,000	2,212	42,212	68,363	110,575
1903	64,626	1,447	66,073	60,605	126,678
1904	36,689	1,694	38,383	76,815	115,198
1905	67,713	3,774	71,487	72,567	144,054
1906	69,493	5,541	75,034	47,590	122,624
1907	46,246	10,139	56,385	88,596	144,981
1908	23,893	3,107	27,000	72,831	99,831
1909	33,112	2,800	35,912	74,316	110,228
1910	32,138	1,000	33,138	73,904	107,042
1911	32,255	900	33,155	88,573	121,728
1912	27,767	355	28,122	59,804	87,926
1913	61,666	2,300	63,966	60,600	124,566
1914	41,509	....	41,509	21,882	63,391
1915	46,329	1,400	47,729	36,878	84,607
1916	44,934	[b] 12,200	57,134	36,454	93,588
	717,418	52,569	769,957	1,124,195	1,894,182

[a] By fiscal years ending June 30.

[b] Estimated. About 75 per cent of this production is bituminous.

With the opening of the high-grade coal deposits of the Bering River and Matanuska fields the question of a market for these fuels becomes important. This matter was discussed at some length in a publication issued seven years ago.[1] The general analysis of the fuel market on the Pacific seaboard there presented still holds true. Time has not been available, however, to collect the necessary data on which to base an estimate of the present market for Alaskan coal. Since 1910 the Alaskan coal consumption has declined, owing to an increased use of oil. (See table, p. 40.)

It seems desirable to summarize briefly the information available regarding coal consumption in the Pacific States,[2] where Alaskan fuel must find its principal export market. It need hardly be added that under present industrial conditions coal production and distribution vary greatly from year to year. No data relating to this matter for 1916 are available, but even if they were it would probably be better to use the figures for 1915 for the purpose of estimating a possible coal market, as the coal trade in that year was in a far more normal condition than in 1916. The subjoined table, based on Lesher's report, presents the coal consumption of the three Pacific Coast States. The railroad coal is separated from that used for other purposes, as the data do not permit a definite statement that it was all burned in the State to which it is credited. The railroad consumption of fuel, as given in the table, represents the coal mined or purchased by the railroads in these States.

Coal consumption in Pacific Coast States, 1915, in net tons.

	Washington.	Oregon.	California.
Total consumption, except railroads	1,087,684	342,963	332,472
Used by railroads	1,149,446	5,000	....
Imports	128,239	1,454	284,225
	2,365,369	349,417	616,697

The above table shows that 3,311,483 tons of coal was consumed in the Pacific Coast States during 1915. No data are available for the years immediately preceding, but the consumption for the same group of States in 1908 is estimated to have been 4,372,300 tons.[3] This falling off is of course due to the greatly increased use of California oil. The petroleum output of the California fields was 44,854,737 barrels in 1908 and 86,591,535 barrels in 1915.[4]

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[1] Brooks, A. H., Alaska coal and its utilization: U. S. Geol. Survey Bull. 442, pp. 47-100, 1910; reprinted as Bull. 442-J, 1914.

[2] Lesher, C. E., Coal in 1915, Part B, Distribution and consumption: U. S. Geol. Survey Mineral Resources, 1915, pt. 2, pp. 433-513, 1916.

[3] Northrop, J. D., Petroleum in 1915: U. S. Geol. Survey Mineral Resources, 1915, pt. 2, p. 706, 1916.

[4] Brooks, A. H., op. cit., pp. 84-85.

Another factor in the west coast coal trade is the opening of the Panama Canal. Up to the present time the shipments through the canal to the west coast have been chiefly naval coal, with some anthracite and probably a little blacksmith coal. In 1915 about 144,000 tons[1] reached the west coast through the canal. No doubt under normal conditions the eastern coal will seek a market on the Pacific seaboard by the canal route and may compete directly with coal shipped from Alaska.

As the Alaskan coal could not be sold east of the mountains, owing to the long railway haul, it is desirable to estimate the coal consumption on the Pacific slope. No exact data are available on which to base such an estimate. It is possible, however, to arrive at approximate figures based on certain assumptions, and this has been done with the help of Mr. Lesher. In making this estimate it is assumed that all the coal from the Roslyn field of central Washington is consumed east of the mountains and that the same is true of the coal shipped to Washington and Oregon from the Montana, Utah, and Wyoming fields. The results are presented below, together with the Alaskan coal consumption (p. 26).

Estimate of coal consumption of the Pacific slope, 1915, in net tons.

California	610,000
Oregon	300,000
Washington	2,300,000
Alaska	90,000
	3,300,000

The high-grade coals of Alaska are of better quality than any others found on the Pacific seaboard. They should be of special value for the bunker trade. The increased use of oil-burning engines on ocean vessels is illustrated by the subjoined table, in which the bunker trade for the years 1908 and 1915 is compared. This table is based on data furnished by Mr. Lesher. As the statistics on bunker consumption are not entirely complete the figures for 1915 are in part based on estimates. Of the 319,000 tons of bunker coal consumed in 1915 about 180,000 tons was consumed by vessels engaged in foreign trade. This does not include about 85,000 tons of coal furnished to vessels in the Hawaiian Islands.

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[1] Lesher, C. E., op. cit. This does not include shipments to Manila, 23,668 tons, and to Honolulu, 11,846 tons.

Bunker coal supplied to steamers in ports of Pacific Coast States and Alaska in 1909 and 1915, in net tons.

	1909	1915 [a]	Decrease.
California ports	186,287	170,000	16,000
Oregon ports	17,426	5,000	12,000
Washington ports	406,564	136,000	271,000
Alaska ports	15,009	8,000	7,000
	625,286	319,000	306,000

[a] Estimated.

Both the Matanuska and Bering River coal fields contain high-grade coking coals. As there is a scarcity of coking coal on the west coast Alaska coke should find a ready market. The figures for coal consumption on the Pacific slope presented in a previous table (p. 28) included that manufactured into coke. It will be well, however, to present the coke consumption by States.[1]

Coke consumed in Pacific Coast States in 1915, in net tons.

	Domestic.	Foreign.	Total.
California	42,268	15,849	58,117
Oregon	1,283	....	1,283
Washington	78,815	1,033	79,848
	122,366	16,882	139,248

Of the domestic coke shown in the above table about 65,000 tons was furnace coke. There are no data on the use to which the imported coke was put. Most of the domestic furnace coke used on the west coast is from the State of Washington, but a little is brought by rail from Utah, Colorado, and New Mexico.

The annual consumption of coke on the west coast has not changed greatly for some years. In 1908 California, Oregon, and Washington consumed about 126,000 tons;[2] in 1915, 139,000 tons. About 217,000 tons of coal was utilized in manufacturing the 139,000 tons of coke in 1915.

Both the Matanuska and Bering River coal fields contain considerable anthracite. So far as known, most of this Alaskan anthracite is more or less crushed and probably will not produce a large percentage of lump coal. There is also a good deal of the high-grade bituminous coal which is crushed, and one of the important problems in connection with finding a market for the Alaskan fuel is the economic utilization of this crushed coal.

Lesher[3] has estimated that in 1915 the Pacific Coast States consumed in all only 2,600 tons of domestic anthracite. In addition to this there was imported 740 tons of coal which was classed as anthracite but about the classification of which there is some question. Be that as it may, the total annual consumption of anthracite along the Pacific seaboard amounts to only a few thousand tons. Therefore, if Alaskan anthracite is mined, a market for coal of this class will have to be built up. The most promising immediate market for anthracite would seem to be in the Territory itself.

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[1] Lesher, C. E., Coke in 1915: U. S. Geol. Survey Mineral Resources, 1915, pt. 2, pp. 515–558, 1916.

[2] Brooks, A. H., Alaska coal and its utilization: U. S. Geol. Survey Bull. 442, p. 86, 1910.

[3] Lesher, C. E., Coal in 1915, Part B, Distribution and consumption: U. S. Geol. Survey Mineral Resources, 1915, pt. 2, pp. 488, 491, 492, 1916.

British Columbia coal, notably that from Vancouver Island, is an important factor in the fuel market of the Pacific Coast States. Therefore the following official data relating to the British Columbia coal production are here included:

Coal produced in British Columbia, 1913 and 1914, in tons.[a]

	Vancouver Island.	Nicola and Princeton.	Crowsnest and East Kootenay.	Total.
1913.				
Sold for consumption in Canada	715,259	276,528	319,856	1,311,643
Sold for export to United States	107,885		590,935	698,820
Total sales	823,144	276,528	910,791	2,010,463
Used for making coke or brick			485,271	485,271
Used for colliery consumption, etc	104,736	17,903	96,047	218,686
Total production	927,880	294,431	1,492,109	2,714,420
1914.				
Sold for consumption in Canada	674,928	134,995	159,598	969,521
Sold for export to United States	236,004	3,006	436,109	675,119
Total sales	910,932	138,001	595,707	1,644,640
Used for making coke or brick			398,117	398,117
Used for colliery consumption, etc	106,751	17,391	72,900	197,042
Total production	1,017,683	155,392	1,066,724	2,239,799

[a] McLeish, John, Annual report on the mineral production of Canada during the calendar year 1914: Canada Dept. Mines, Mines Branch, Pub. 384, p. 232, 1915.

The figures for production in 1913 probably represent more norma conditions of the British Columbia coal-mining industry than those for 1914, when the industry was more or less affected by the war. In 1915 British Columbia produced 2,089,966 tons of coal and 275, 375 tons of coke.[1] Details regarding the source of this coal by districts and its distribution are lacking at this writing.

The Vancouver Island coals for which statistics are given in the above table "are high-volatile bituminous coals of fair quality."[2] They are, however, inferior to the bituminous coals of the Matanuska and Bering River fields of Alaska. These are the coals with which the Alaskan coal may come into direct competition.

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[1] McLeish, John, Preliminary report on the mineral production of Canada during the calendar year 1915: Canada Dept. Mines, Mines Branch, Pub. 408, pp. 19-20, 1916.

[2] Dowling, D. B., Coal fields of British Columbia: Canada Geol. Survey Mem. 69, p. 69, Ottawa, 1915.

PETROLEUM.

INTRODUCTION.

Petroleum seepages are known in Alaska at four localities, all on the Pacific seaboard. These, named from east to west, are Yakataga; Katalla, on Controller Bay; Iniskin Bay, on Cook Inlet; and Cold Bay, on Alaska Peninsula. A petroleum residue has been found near Smith Bay, on the Arctic coast, and seepages are reported to occur near Wainwright Inlet, about 100 miles west of this locality. At Katalla, Cold Bay, and Iniskin Bay there has been some drilling for oil, and in the Katalla field several productive wells have been opened.

The discovery of oil seepages in different parts of the Yukon basin, notably in the Tanana Valley, has been reported at different times. These occurrences, so far as investigated, have all proved to be those skims of oxide of iron which, especially in combination with marsh gas, simulate seepages of petroleum. Those examined occur in alluvial deposits. Some have been encountered in placer mining, where shafts have been sunk below the level of permanent ground frost. As prospectors have been frequently misled by such occurrences into the belief that they had found petroleum seepages, the following note describing simple tests, for which the writer is indebted to Mr. David White, is included:

> Among the most important surface indications of the presence ot oil and gas deposits are films of oil on water, oil seeps or springs, gas emanations, asphaltic deposits, lenticular accumulations of rock salt or sulphur, and rocks saturated with oil and emitting the odor of petroleum. However, most of these indications should be examined critically with respect to genuineness as well as natural source, especially under certain conditions, and they may require the scrutiny of a specialist in geology or petroleum chemistry. In most of the supposed petroleum seepages the oil-like substance is in reality iron oxide, which commonly forms an iridescent film on the surface of water, especially in marshy places. It can be readily recognized by the fact that it will not burn, and when stirred with a stick breaks into flakes and does not cover the water evenly, like an oil film. It also lacks the odor of petroleum, and if a little is put on a piece of muslin and pressed with a hot flatiron the familiar iron stain is formed. Another simple test for determining the nature of the film is to absorb some of the substance in a blanket or burlap and after allowing it to dry to set fire to it. If the substance is petroleum it will burn with a long, vigorous flame and will give forth the odor of petroleum.

The constantly increasing demand for petroleum, especially refining oils such as occur in Alaska, has renewed interest in the oil fields of the Territory. This has led to a demand for the information about these fields, which is scattered through a number of Survey publications, some of them now out of stock. A brief summary of what is known of these fields seems timely, for there is no official report that deals with the entire subject. The following compilation,[1] though it contains but little new information, will, it is hoped, be useful to those who are interested in these fields. It has been prepared principally from reports by G. C. Martin, who has investigated the Katalla, Cook Inlet, and Alaska Peninsula oil fields. A. G. Maddren has also made a reconnaissance of the Yakataga oil fields. The data here presented are taken largely from the following publications:

*Martin, G. C., The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits: U. S. Geol. Survey Bull. 250, pp. 9–27, 1905. 15 cents.

*Martin, G. C., Geology and mineral resources of the Controller Bay region, Alaska: U. S. Geol. Survey Bull. 335, pp. 112–130, 1908. 70 cents.

Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 126–130, 1912.

*Maddren, A. G., Mineral deposits of the Yakataga district: U. S. Geol. Survey Bull. 592, pp. 143–147, 1914. 60 cents.

The publications marked with an asterisk (*) are out of stock at the Geological Survey but can be purchased of the Superintendent of Documents, Washington, D. C., at the prices indicated.

KATALLA FIELD.

The Katalla field is marked by a series of seepages and gas springs distributed through an eastward-trending belt about 25 miles long and from 4 to 8 miles wide. (See Pl. III.) This zone skirts the north shore of Controller Bay. To the east it extends into the alluvial flats of Bering River and to the west into the flats of Copper River. An oil seepage has been reported still farther west, on Hinchinbrook Island, but this occurrence has not been verified. The field lies in part on the southern slope of a densely timbered highland, whose summits reach 1,200 to 2,000 feet above the sea, and in part on the flats adjacent to the shore line. Drilling has been done at several localities in this belt, but the productive wells are limited to that part of it lying between the town of Katalla and Bering River.

The surface rocks are a series of intensely folded and faulted shales, sandstones, and conglomerates, with some small basalt or diabase dikes and sills. The general structural trend is about N. 20° E., and the line of seepages lies diagonal to this trend. As much of the field is masked with a dense growth of vegetation, details are lacking on the minor features of structure. Certain seepages or groups of seepages are closely associated with faults or with subordinate anticlines. No definite law of association of the petroleum with tectonic features, however, has yet been established.

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[1] This statement is in part a reprint of Brooks, A. H., The petroleum fields of Alaska: Am. Inst. Min. Eng. Trans., vol. 51, pp. 611–619, 1916.

KATAGA OIL FIELD

West of Katalla seepages belonging to the same belt have been found in surface rocks or more or less metamorphosed graywackes and slates.

The shale, sandstone, and conglomerate series is of Tertiary age and probably older than the Tertiary coal measures of the Bering River field, which lies about 25 miles to the northeast. All these Tertiary beds are undoubtedly younger than the metamorphosed graywackes and slates, which may be of Mesozoic or Paleozoic age.

It is evident from the above discussion that the source of the oil is unknown. A source in the metamorphic graywackes is of course very improbable. It may be derived from the Tertiary beds or from strata not exposed at the surface. A possible explanation of the seepages in the metamorphic rocks is that these have been thrust over younger oil-bearing strata.

Katalla, the distributing point in this field, is a small settlement at which freight can be landed from scows only during favorable conditions of the wind. During the period of oil excitement some use was made of Controller Bay, 15 miles east of Katalla. Within its shelter ships discharged on scows, and these were landed at the mouth of Bering River. Plans have been formulated for developing the Bering coal field by a branch from the Copper River Railroad, connecting with tidewater at Cordova, on Prince William Sound. (See Pl. III.) Another plan contemplates the building of a railway from a terminal on Controller Bay. Either plan could be made to serve the Katalla field with but little additional expense. Controller Bay could also be used as a petroleum-shipping point, without the agency of a railroad, by building short pipe lines to tidewater. There is ample timber available for structural purposes.

The Katalla seepages were known as early as 1880 but appear not to have attracted any particular attention until about 1897. The first drilling was done in 1901, and a number of holes were sunk during the next three or four years. Some oil was found, but no gushers, and operators were soon drawn away by the California oil excitement. A little oil was pumped from some of these wells in 1907 to supply fuel for railroad construction then in progress near Katalla. In 1911 a small refinery was built near Katalla and supplied with oil from near-by wells. The product found a ready sale at Katalla and on Prince William Sound. This enterprise led to more drilling in this field. Meanwhile, in 1910 all Alaskan oil land was withdrawn from entry, and it has remained in this status ever since. This discouraged all new enterprises, but assessment work is reported to have been kept up on some claims. Patent was granted to a small tract in the new Katalla field, which had been located previous to the withdrawal. This constitutes the only Alaskan oil land to which the Government has relinquished title. Production has continued up to the present time from this land, and its output represents the only petroleum production in the Territory. In 1916 the company owning this land was reorganized under the name St. Elias Oil Co. and undertook more systematic development. Several wells were cleaned out and connected for pumping. By this means the production was increased to about 30 or 40 barrels a day, obtained from six wells. Preparations were also made to drill some new holes. Plans for developments in this field during 1917 are also being formulated by another company.

In all about 26 holes have been drilled in the Katalla field, of which at least a dozen have struck some oil. The deepest well is about 1,600 feet deep, but the geology of the field is so complex that the actual depth is not significant of the position of an oil pool. Some natural gas was encountered in the drilling.

YAKATAGA FIELD.

The Yakataga petroleum field lies about 80 miles east of Katalla. (See Pl. III.) Here a series of seepages marks a zone about 20 miles in length and half a mile to 2 miles from the beach. The extension of this line to the west carries it into the Pacific, and to the east into an unexplored and ice-covered region tributary to Icy Bay. Prospectors report the presence of a strong oil seepage near Yahtse River, about 15 miles east of the locality to which the belt has been actually traced. There is also a less definite report of the occurrence of seepages along the mountain front between Yakutat and Lituya Bay, about 200 miles east of Yakataga. What little is known of the geology of this region lends some support to this rumor.

The line of Yakataga seepages lies for the most part in a series of short valleys separated from the coastal plain by a low-wooded ridge and drained by streams whose courses are transverse to this ridge. About a dozen seepages have been found, most of which are little more than exudations along joint cracks. One, however, on Johnston Creek is roughly estimated to discharge a barrel or more of petroleum a day.

So far as determined, all these seepages lie along a sharp anticline whose southern limb is about vertical and whose northern limb dips inland at 15° to 45°. The exposed rocks consist of sandstone overlain by fine-textured shale of Oligocene or lower Miocene age. No drilling has been done in this field, so that there is no information at hand as to the underground geologic conditions. Speculation as to the source of the petroleum is therefore futile.

The Yakataga field is now almost inaccessible, as all landings must be made on a beach exposed to the full sweep of the Pacific. Most of the freight for the few placer miners in the district is brought from

Katalla by launch when the winds are favorable to a landing. The overland route along the beach is difficult, though it probably could be utilized for a pipe line or a narrow-gage railroad. The marked recession of a glacier at the east end of the field during the last few years has revealed a small indentation known as Icy Bay, in which shelter may possibly be had, though at present it is in part blocked by ice cakes. If the glacier continues to retreat, the Yakataga field will probably be rendered accessible. There is abundant timber suitable for structural purposes in the district.

Oil claims were staked in the Yakataga field as early as 1897 or 1898, but none of them have been patented. It is reported that up to very recently at least some kind of assessment work was done on these claims, but there has been no drilling. In 1898 a survey for a pipe line was made from Controller Bay to Yakataga.

INISKIN BAY FIELD.

Iniskin Bay is an indentation about 12 miles deep, which, with Chinitna Bay on the north, blocks out an irregular-shaped peninsula on the west shore of Cook Inlet. (See Pl. IV.) The more or less even shore line of this peninsula is broken on the southwest by two small indentations—Oil Bay and Dry Bay. Petroleum seepages have been found in this field near Iniskin, Oil, and Dry bays.

The bedrock of the field is a fine-grained sandstone, with which are interbedded some clay shales. Some beds of conglomerate occur in the sandstone, one of which forms the basal member of the formation, and near the head of Iniskin Bay this bed rests on sheared igneous rocks. The sandstone and the associated sediments, which are of Middle Jurassic age, have a thickness of about 1,100 feet. They are overlain by a shale formation with intercalated conglomerate. The seepages occur in the eastern limb of a broad anticline which has been somewhat faulted. Drilling has not gone deep enough to indicate whether the altered igneous rocks underlie the whole field as they do at the western margin. The evidence in hand points to the conclusion that the sandstone is the source of the petroleum.

The field is readily accessible from the good harbors lying both north and south. These are occasionally blocked by ice floes but are usually accessible throughout the year. There is some timber in the district, but this is chiefly of an inferior quality. Timber could be brought from other parts of the Cook Inlet region, however, at no great expense.

The oil seepages of Iniskin Bay appear to have been known to the Russians before the acquisition of Alaska by the United States. The first well was drilled in this field near Oil Bay in 1898 and is reported to have reached a depth of 1,000 feet. Gas is said to have been found at a depth of 190 feet and oil at 700 feet, with an estimated flow of 50 barrels a day. On drilling deeper a strong water pressure cut off the flow of oil. A little oil and gas were encountered in a second well, drilled in 1904, which was abandoned at a depth of 450 feet on account of caving of the shale which was penetrated. A third well near by was sunk to a depth of 930 feet. At about 770 feet three thin oil sands were pierced, which are estimated to have yielded 10 barrels a day. A little drilling was done during 1905 and 1906, but of the results there is no record. No work has been done in the field since 1906.

ALASKA PENINSULA.

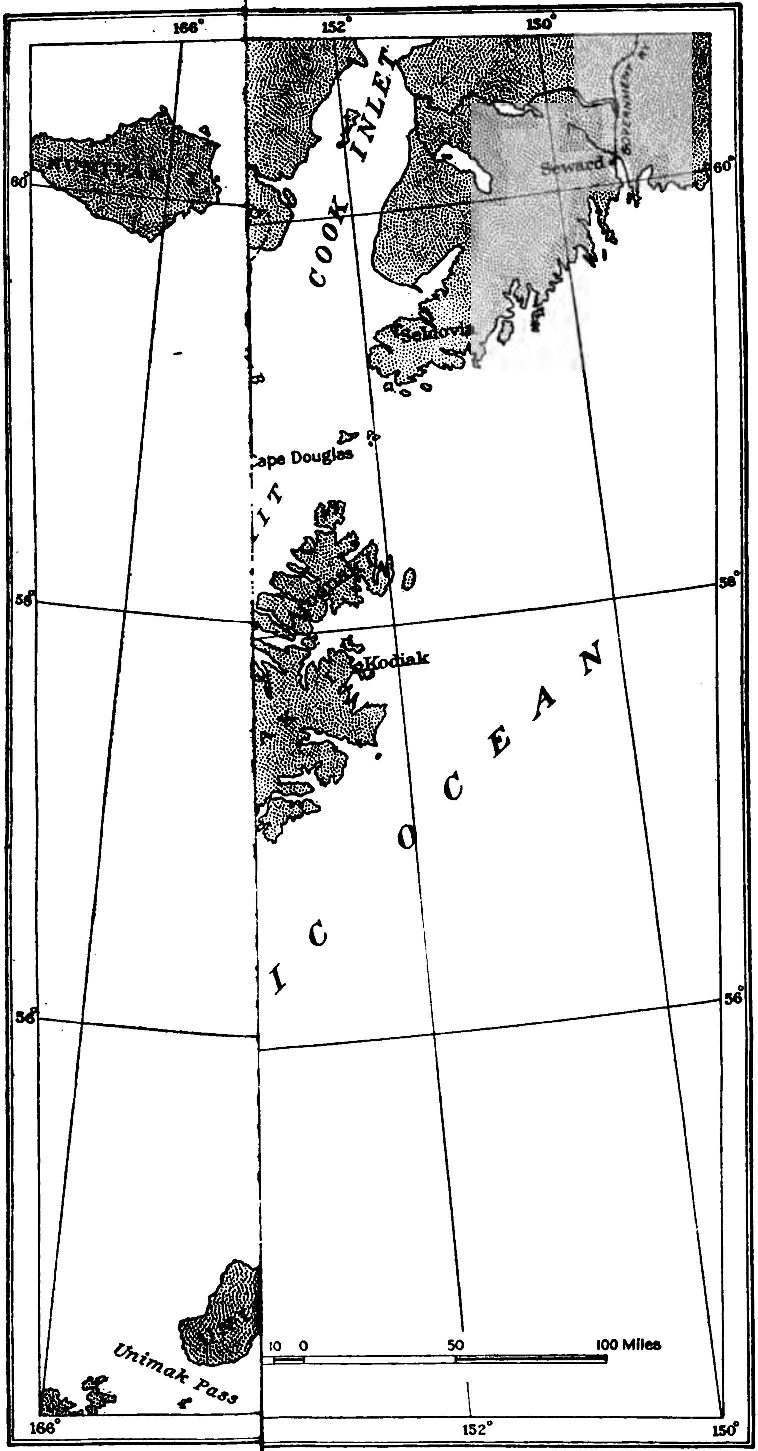
Petroleum seepages on Alaska Peninsula were known to the Russians previous to 1866. Occasional references, though indefinite as to locality, are found in the earlier literature dealing with Alaska, but apparently no thought was given to their possible commercial importance until the Alaska oil boom started, about 1900. The only drilling done on the peninsula is at Cold Bay, described below. Oil seepages have been found at the base of the peninsula near Kamishak Bay, west of Cape Douglas, and reported near Becharof Lake. The area between these localities is not explored.

Cold Bay is an indentation on the Pacific shore of the Alaska Peninsula nearly opposite the south end of Kodiak Island. (See Pl. IV.) The adjacent area, which is untimbered, consists of rounded hills rising to altitudes of less than 1,000 feet. Above these rise some higher peaks, made up chiefly of volcanic rocks.

The country rock of the area in which the seepages occur is a sandstone and shale formation carrying a little limestone; it is of Middle Jurassic age and about 2,000 feet thick. It is underlain by shale, limestone, and chert (Triassic) and overlain by Middle Jurassic arkose conglomerate, sandstone, and shale. The youngest rocks of the district are volcanic, chiefly andesite and basalt. It is a significant fact that the oil-bearing member of this series is of the same age as the oil-bearing beds of the Iniskin Bay field. The main structural features are broad, open folds whose axes parallel the coast, trending about northeast. The dips of the strata do not generally exceed 15°. Some faults have also been noted.

There are a number of oil seepages in this field, some of which are strong. At one of these seepages there is a considerable flow of gas.

The harbor at Cold Bay is open throughout the year, and the contour of the region makes it readily accessible. There is no timber in the district.


166°
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NUNIVAK
COOK INLET
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Two wells were drilled in the Cold Bay field in 1903 and 1904. One of them reached a depth of 1,500 feet and is reported to have pierced several oil sands. No drilling has been done in this field since 1905.

ARCTIC COAST.

E. de K. Leffingwell, who spent several years exploring the north coast of Alaska, has reported the occurrence of petroleum residue about 100 miles east of Point Barrow. (See Pl. I, in pocket.) Mr. Leffingwell describes this material as occurring near Smith Bay,[1] in a mound several hundred yards in diameter and standing about 150 feet above the level of the tundra. It contains considerable vegetable matter and silt, but appears to be the residue of a petroleum containing an asphaltic base. Nothing is known of the geology at this locality, but in the general province in which it occurs there is a series of horizontal Tertiary sediments overlying gently folded Mesozoic sediments.

An oil seepage is reported to have been discovered in 1914 near Wainwright Inlet, about 100 miles west of Smith Bay. If this report is true it suggests that there may be an east-west oil-bearing belt traversing this part of the Arctic coastal plain. Both Smith Bay and Wainwright Inlet are shallow lagoons that are locked in ice for at least 10 months of the year. Even if an oil pool were found in this northern field, the conditions of transportation would prohibit present commercial development.

CHARACTER OF THE PETROLEUM.

Alaskan petroleum, so far as its quality is known, is a refining oil similar to that of Pennsylvania, and has a high percentage of volatile compounds, a paraffin base, and but little sulphur. The accompanying table will serve to indicate the quality of the oil from the Katalla, Yakataga, Iniskin, and Cold Bay fields. All the samples from the Yakataga, Cold Bay, and Iniskin fields and part of those from the Katalla field, however, are from seepages in which there has been some loss of the volatile compounds.

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[1] Brooks, A. H, The mining industry [of Alaska] in 1908: U. S. Geol. Survey Bull. 379, pp. 61, 62, 1909.

Summary of analyses and tests of Katalla and Yakataga petroleum.

Locality.	Color.	Gravity.		Flashing point (°F.).	Benzine (per cent).	Kerosene, (per cent).	Lubricating oil (per cent).	Residue, coke, and loss (per cent).
		Specific.	Baumé (°).					
KATALLA FIELD.								
Katalla, well 10[a]		0.8280	39.1		21.0	51.0	28.0	
Katalla, well 10[b]		.7558	45.9		38.5	31.0	21.5	9.0
Katalla, well 10[c]	Light green	.7957	45.9	70-80	38.5	31.0	21.5	9.0
Do		.800			34.2	34.4	16.5	14.5
Katalla, well 10[d]	Dark red	.802		60				
Do	do	.790		60				
(?)[d]		.869				19.0	78.6	1.7
(?)[d]		.914				9.0	87.6	2.7
(?)[d]		.800			24.8	53.9	16.7	1.2
Katalla Meadow [d]	Dark brown	.929		240				
Do		.901		156				
Do		.874		156				
Do		.869		152				
Do		.961		266				
Burls Creek [d]	Dark red-brown	.942		234				
YAKATAGA FIELD.								
Johnston Creek [d] [e]	Dark brown	.964		200				
Do	do	.879		178				
Poule Creek [d] [e]	do	.970		250				
Do	do	.881		67				
Do	do	.914		156				
Crooked Creek [d] [e]	do	.921		172				
Oil Creek [d] [e]	do	.855		108				
Yakogelty [d] [e]	do	.937		246				
Morrison Creek [d] [e]	do	.991		270				
Argyll Creek, Icy Bay [d] [e]	do	.962		310				

[a] Sample collected by G. C. Martin, test by Penniman & Browne, U. S. Geol. Survey Bull. 335, p. 121, 1908.

[b] Oliphant, F. H., The Production of petroleum in 1902: U. S. Geol. Survey Mineral Resources, 1902, p. 583, 1903.

[c] Stoess, P. C., The Kayak coal and oil fields of Alaska: Min. and Sci. Press, vol. 87, p. 65, 1903.

[d] Redwood, Boverton, Petroleum, vol. 1, 2d ed., p. 198, 1906.

[e] The exact localities of seepages where these samples were taken are not known, but they are believed to be in the Yakataga field.

Tests of samples of seepage petroleum from Oil Bay and Cold Bay.[a]

[Penniman & Browne, analysts.]

	Oil Bay.	Cold Bay.
Specific gravity at 60° F.	0.9557 (16.5° B.)	0.9547 (16.6° B.)
Distillation by Engler's method:		
Initial boiling point °C.	230	225
Burning oil (distillation up to 300° C., under atmospheric pressure) per cent.	13.2 (29.5° B.)	13.3 (29.6° B.)
Lubricating oils (spindle oils) (120 millimeters pressure, up to 300° C.) per cent.	39.2 (22.6° B.)	28.3 (23.8° B.)
Lubricating oils (120 millimeters pressure, 300°-350° C.) per cent.	19.6 (17.9° B.)	18.3 (18° B.)
Paraffin oils (by destructive distillation under atmospheric pressure) per cent.	22.4 (20.4° B.)	32.4 (20.4° B.)
Coke and loss do.	5.6	8.1
Total sulphur do.	.098	.116

[a] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, p. 59, 1905.

The distillation of the lubricating oils under diminished pressure, corresponding to refinery practice, was carried on until signs of decomposition set in. The resulting residue was unsuitable for making cylinder stock and was therefore distilled for paraffin oils. These paraffin oils contain a considerable quantity of solid paraffin. It was not practicable to determine the amount of the material with the small amount of oil at our disposal.

The iodine absorption of the oils and distillates has been determined by Hanus's method (solution standing 4 hours), and is here tabulated:

	Oil Bay.	Cold Bay.
Burning oil........per cent of iodine..	17.8	17.2
Lubricating oil........do....	26.2	27.2
Heavy lubricating oil........do....	35.8	35.2

These iodine numbers upon the lubricating oils were obtained upon the samples. For comparison, samples of similar oils were obtained from the Standard Oil Co., and the iodine numbers determined as follows:

Light distilled lubricating oil (spindle oil)...per cent of iodine..	32
Dark lubricating oil (engine oil)........do....	45.4

The burning oils were tested in a small lamp and found to give a good flame. All the oil was consumed without incrusting the wick or corroding the burner.

The sample of crude oil from Cold Bay was distilled in such a way as to give the maximum yield of burning oil; under these conditions 52.2 per cent of fair quality burning oil was obtained.

The oils are entirely similar; both have paraffin bases, and the products of distillation are "sweet." We are informed that these samples are "seepage oils." If a sufficient yield can be obtained by drilling a very suitable oil for refinery purposes may be expected, containing a very much larger quantity of the more desirable lighter products.

SUMMARY AND CONCLUSIONS.

The Katalla field is a region of closely folded and faulted Tertiary rocks, possibly comparable in its structure to the California fields. Much of the drilling in this field was done without any regard to geologic structure, and but few good logs are available. The presence of oil is indicated by the success achieved, but it will require further drilling to determine the presence or absence of large pools. At Yakataga the structure of the oil-bearing formation appears to be much simpler, and it ought to be possible to test the field without a very large amount of drilling.

In both the Iniskin and Cold Bay fields Middle Jurassic sandstone forms the country rock in the oil-bearing area. The open folding should be favorable to oil pools; on the other hand, some faulting has been observed. There is reason to believe that the oil-bearing formation found in these two fields may have a wider distribution in the Alaska Peninsula. Whether it carries petroleum at other localities has not been determined. On the whole, there is good hope of finding petroleum in the Alaska Peninsula.

As the Alaskan petroleum is a refining oil similar to that of Pennsylvania it should be able to compete with the product from California in spite of the higher cost of operation. The high cost is due in part to conditions of transportation which it is possible to improve The present market for petroleum of the Alaskan grade justifies the systematic prospecting of the more accessible fields of the Territory.

This work will of course not be undertaken until Alaskan oil lands are thrown open to exploitation. Meanwhile large quantities of petroleum and petroleum products are annually shipped to Alaska, as shown by the following table. The total value of the shipments of petroleum and petroleum products to Alaska was $1,277,319 in 1916 and $904,369 in 1915.[1]

Petroleum products shipped to Alaska from other parts of the United States, 1905–1916, in gallons.[a]

Year.	Oil used for fuel, including crude oil, gas oil, residuum, etc.	Gasoline, including all lighter products of distillation.	Illuminating oil.	Lubricating oil.
1905	2,715,974	713,496	627,391	83,319
1906	2,688,940	580,978	568,033	83,992
1907	9,104,300	636,881	510,145	100,145
1908	11,891,375	939,424	566,598	94,542
1909	14,119,102	746,930	531,727	85,687
1910	19,143,091	788,154	620,972	104,512
1911	20,878,843	1,238,865	423,750	100,141
1912	15,523,555	2,736,739	672,176	154,565
1913	15,682,412	1,735,658	661,656	150,918
1914	18,601,384	2,878,723	731,146	191,876
1915	16,910,012	2,413,962	513,075	271,981
1916	23,555,811	2,844,801	732,369	373,046
	170,814,799	18,254,611	7,165,038	1,794,714

[a] Compiled from Monthly Summary of Foreign Commerce of the United States, 1905 to 1916, Bureau of Foreign and Domestic Commerce.

STRUCTURAL MATERIAL, ETC.

One large marble quarry was operated in 1916 at Tokeen, in the Ketchikan district, and a small one in the Wrangell district. Gypsum mining on Chichagof Island, Sitka district, continued on about the same scale as in the previous year. Work was continued on a barite deposit located at Lime Point, on the west side of Prince of Wales Island.[2] The construction of a reduction plant for this mine was begun at Sulzer in 1916. Assessment work was done on a barite deposit in the Wrangell district.[3] No barite was shipped from Alaska in 1916. Development work was continued on two graphite deposits—one belonging to the Uncle Sam Alaska Mining Syndicate and the other to the Alaska Graphite Co.—in the Kigluaik Mountains, 5 to 10 miles south of the Imuruk Basin.[4] Though no graphite was shipped, there was a considerable production. The Alaska-Graphite Co. has built a wharf at tidewater and in 1916 brought in a caterpillar tractor to haul the graphite from the mine. The truck did not arrive in time for use during 1916.

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[1] Monthly Summary of Foreign Commerce of the United States, December, 1916, p. 73, 1917.

[2] Chapin, Theodore, Mining developments in southeastern Alaska: U. S. Geol. Survey Bull. 642, p. 104, 1916.

[3] Burchard, E. F., A barite deposit near Wrangell: U. S. Geol. Survey Bull. 592, pp. 109–117, 1914.

[4] Smith, P. S., Investigations of the mineral deposits of Seward Peninsula: U. S. Geol. Survey Bull. 345, p. 250, 1908; Recent developments in southern Seward Peninsula: U. S. Geol. Survey Bull. 379, pp. 300–301, 1909.

REVIEW BY DISTRICTS.

The subjoined review is intended to summarize briefly the principal developments in all the districts. Owing to the failure of some operators to make reports, the information at hand about mining in some of the districts is scant, and some are treated at greater length in other sections of this volume. The space here devoted to any district is therefore not necessarily an indication of its relative importance. The arrangement is geographic, from south to north.

SOUTHEASTERN ALASKA.

Eight gold lode mines, nine copper mines, three placer mines, two marble quarries, and one gypsum mine were operated in southeastern Alaska in 1916. The value of the mineral production from these mines is as follows: Gold, $5,524,940; copper (3,526,700 pounds), $867,570; silver, marble, lead, gypsum, etc., $639, 500; total, $7,032,010. In 1915 minerals to the value of $6,090,571 were produced in southeastern Alaska.

As in the past, much the largest mining operations were in the Juneau district. All the productive copper mining of southeastern Alaska was in the Ketchikan district, but there was some prospecting for copper in the Wrangell district. Placer mining in 1916 was limited to the Porcupine district. Mining developments in all these districts are described elsewhere in this report.

The Chichagof gold mine continued to be the only productive property in the Sitka district during 1916. Its workings include two shafts 1,020 and 820 feet deep, a 3,900-foot adit, and 11,650 feet of drifts. Of these workings 5,250 feet was opened in 1916. The 20-stamp mill was operated the entire year; the 10-stamp mill, owing to shortage of water power, only for 236 days.

At the near-by Hurst property two adits, aggregating some 400 feet in length, have been driven. The developments in 1916 consisted in the driving of crosscuts on the lower level. A lode deposit about 17 miles north of the Chichagof mine, near Pinta Cove, was opened by the Juneau Sea Level Copper Mining Co. A specimen of ore received from the owners of this property showed it to be pyrrhotite with chalcopyrite. Besides copper the owners report the ore to carry both nickel and a small amount of cobalt. In 1916 a shaft was sunk on the deposits to a depth of 75 feet and a crosscut driven for 75 feet, which is said to reveal a lode 27 feet wide. This deposit has not been examined by any Survey geologist.

YAKUTAT AND LITUYA BAY REGION.

As in the past, gold beach-placer mining continued in a small way in the Yakataga district during 1916. Beach placers were first found at Lituya Bay in 1886 and were mined for a number of years by means of rockers. This region is so difficult of access that it has of late attracted but few prospectors, but in 1916 there was some revival of interest in this field. Only a brief statement about this region has been published by the Survey,[1] and as this is in a publication now out of stock it is here reprinted:

> Lituya Bay forms a deep indentation in the coast line 50 miles to the northwest of Cross Sound. Although it is an excellent harbor, a bar composed of large boulders and gravel wash almost locks the entrance, and through the boat channel, which is but 100 feet in width, the tide rushes at great velocity, so that it is dangerous to enter except at slack water during calm weather.
>
> The lowlands flanking the abrupt mountain slopes at the head of the bay are composed of Pliocene conglomerate and shale beds carrying narrow seams of coal, the latter of no commercial importance. These strata overlie a belt of slates and greenstones, which in turn overlie the metamorphic schists exposed along the precipitous shore at the head of the bay. The mountain range in the background is composed essentially of an intrusive granodiorite. Indications of mineralization were observed in these schists bordering the granite belt, and from them the placer gold occurring in the beach sands along the coast is supposed to have originated.
>
> The auriferous beach sands are distributed along the Pacific shore to the northwest of the bay for a distance of about 10 miles, and similar occurrences are reported at Yakutat. These auriferous deposits consist of black and ruby sands, occurring in layers from a few inches to a few feet thick and extending in places for 100 yards back from tidewater. The black or magnetite sands are by far the richest, and a pan test gave numerous fine colors ranging from a fraction of a cent to several cents in value.
>
> At a point 4 miles northwest of Lituya Bay a river which flows nearly parallel with the shore for about 3 miles enters the ocean, and here the fine wash which is derived from the mountain streams and carried in suspension is deposited by the counteraction of the surf against the stream current. During periods of high tide and storms these auriferous sands are concentrated by the waves in layers high up on the beach. Since 1890 these deposits have been worked at intervals and are reported to have produced in 1891 $15,000. In later years even higher returns are said to have been obtained, but no authentic statements could be procured.
>
> In 1901 the Lituya Bay Gold Mining Co. built a large warehouse and flumes and installed machinery to conduct large-scale operations, but the limited extent of the pay streaks and lack of near-by water for power and hydraulicking purposes prevented it from furthering the work to a successful outcome. Small parties of miners, however, at different periods have worked these deposits with shovel, sluice box, and rockers to good advantage and report that the auriferous beds yielded from $5 to $10 a day per man. The presence of gold in these sands appears to warrant a thorough prospecting of the mineral-bearing schists which traverse the head of Lituya Bay and parallel the coast line.

It is reported that in 1916 a number of beach miners worked in the Lituya Bay region, and that some gold-bearing gravels have been found in the streams tributary to Lituya Bay. As it also appears to be pretty definitely established that some of the beach sands carry a little platinum, further prospecting is justified.

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[1] Wright, F. E. and C. W., Lode mining in southeastern Alaska: U. S. Geol. Survey Bull. 314, pp. 64-65, 1907.

COPPER RIVER REGION.

Mining in the Copper River region during 1916, as in the preceding year, included the development of copper mines in the Kotsina-Chitina copper belt and placer mining in the Nizina and Chitina districts. There was also some prospecting of gold lodes and placers in the Tiekel district and a little placer mining in the Bremner and Nelchina districts. The copper production of this region was much larger than in the previous year. Three mines—the Bonanza-Kennecott, Jumbo-Kennecott, and Mother Lode—were operated on a productive basis throughout the year, but shipments from the Mother Lode were limited to the winter. Considerable development work was done on half a dozen other copper properties, and at several some ore was incidentally mined. Some of this ore will be sledded to the railroad during the winter, but none is directly accessible in the summer. In addition to systematic development assessment work was done on a number of other copper claims. On the whole there was far more mining development in the copper belt than in the preceding year. A specimen of ore carrying nickel, said to be from Spirit Mountain, in the lower Copper River region, was received by the Survey. Details regarding mining in the copper belt and in the auriferous deposits of the Tiekel River region are presented in another part of this volume by F. H. Moffit.

About 30 placer mines were operated in the Copper River basin in 1916, employing 180 men, and these produced gold to the value of $290,000. Seven hydraulic plants were operated in the Nizina district, of which one, at the mouth of Rex Creek, was installed during 1916. As in the past, the largest mining operations wêre on Chititu Creek and its tributaries and on Rex Creek. In the Chistochina district two hydraulic placer mines were operated. Each of these was equipped with three giants, one being used to remove tailings. One of these plants, on the West Fork of the Chistochina, was built in 1916. It is supplied with water brought through 4,000 feet of ditch and flumes. Drilling was done for testing dredging ground on a group of claims on Jackpot Creek, at the head of the Chistochina. The largest operations in the Chistochina district were on Slate Creek, on the West Fork of the Chistochina. The discovery of platinum in the Slate Creek placers is mentioned on page 22.

Some prospecting was done during 1916 on copper deposits on Rainy Creek, a tributary to the upper Delta River. This deposit actually lies within the Yukon basin, but as it is most accessible from the Copper River side of the divide, it is proper to refer to it under this heading. The deposits are reported to be extensive but to carry only small amounts of copper with a little gold. One specimen obtained from A. H. McNeer showed the rock to be a mineralized diorite carrying several sulphides, including chalcopyrite and possibly pyrrhotite. Another specimen from the same source proved to be a metamorphic rock, possibly an altered limestone made up of epidote, garnet, chlorite, and disseminated sulphides. To judge from these two specimens the ore seems to be of contact-metamorphic origin.

PRINCE WILLIAM SOUND.

The value of the total mineral production of Prince William Sound in 1916 was $2,975,263, compared with $1,340,996 in 1915. Eight copper mines and ten gold mines and prospects, large and small, were operated during the year. As in the past, the tonnage of gold ore mined was very small compared with that of copper ore. The Beatson-Bonanza, Ellamar, and Midas mines were the largest copper producers, and the Granite and Ramsay-Rutherford mines the largest lode-gold producers. There was a revival of interest during the year in the auriferous lodes of the McKinley Lake district, which is not far from the railroad and about 20 miles from Cordova. Plans were made for systematic prospecting in this field. Details regarding mining on Prince William Sound are presented in another chapter of this volume.

KENAI PENINSULA.

The improvements made during 1916 on the old Alaska Northern Railroad, now in Government ownership, have stimulated prospecting in Kenai Peninsula. This railroad, leading inland from the town of Seward, traverses the northeastern part of the peninsula, and when connection is made with the railroad at Anchorage will be part of the through line from the Pacific seaboard to Fairbanks. Wagon roads and trails connect the railroad with the principal localities of gold mining on Kenai Peninsula.

Though work was done on a number of large placer-mining projects during 1916, there was no increase in placer production as compared with the previous year. Gold-lode mining was limited to development work on a number of properties besides those on which only the required assessment work was done. Incidental to this development some ore was recovered and treated in several small mills and arrastres.

Returns from the placer mines of Kenai Peninsula are not complete at this writing. The best information available indicates that the placer-gold output in 1916 had a value of about $70,000, or the same as that of 1915. This was produced chiefly from about 15 mines, employing about 100 men. The largest operations were on Crow and Resurrection creeks. Of the total number of mines, six were operated by hydraulic methods. Considerable work preparatory to hydraulic operations was done on claims on Canyon, Lynx, and Bear creeks. Seven lode properties on Kenai Peninsula produced about 700 tons of ore, which yielded gold to the value of about $17,000. The property of the Kenai Alaska Gold Co. was leased and operated for a part of the season. A lease was taken on the Primrose mine, some developments made, and a little ore treated in a small mill installed during 1916. The Lucky Strike mine was operated on a small scale from June to October. Work was continued on an adit, which was driven to a length of 150 feet. The ore was treated in a 1-stamp prospecting mill. Some work was done at the Grant Lake mine, and the ore was treated in an arrastre. Arrastres were also used in treating ore from the Whistler and Gilpatrick properties. Considerable work was done on the James and Ronan claims, in the Moose Pass district, and the ore was treated in an arrastre. Some preliminary work was also done at the old Skeen-Lechner mine, with a view to making it productive. It is reported that an auriferous quartz lode has been discovered near Tustumena Lake and developed by a 100-foot adit. It is also reported that a promising ledge located on Palmer Creek has been developed by an open cut. The ore is said to carry free gold, sulphides, and considerable galena.

COOK INLET.

In 1916 productive mining on Cook Inlet was practically confined to the Bluff Point coal mine, on the west side of Kenai Peninsula, to which reference is made on page 25, and to the development of the placers on Lewis River, incidentally to which a little gold was produced.

It has long been known that auriferous gravels occur on some of the streams tributary from the northwest to the upper part of Cook Inlet. In 1902 an unsuccessful attempt was made to mine the gravels on Beluga River by hydraulic methods. The project was badly managed, and its failure may have been due to this fact. In 1909 some drilling for dredging ground was done on Beluga River, the results of which are not known, but no dredge was installed. Several years ago some excitement was caused by the discovery of placer gold on either Lewis or Theodore River. The excitement soon died out, but prospecting continued in this region.

The geology, so far as known, is simple.[1] The group of highlands which lies west of the lower Susitna River, and of which Mount Susitna is the highest peak, are made up chiefly or entirely of granodiorite. It is in this highland area that the gold-bearing streams rise. In this general province the margins of the granodiorite masses are favorable localities for the occurrence of mineralization. A belt of Tertiary sediments made up of conglomerates, sandstones, and shales trends northeast from Tyonek. This passes under gravels but has been recognized on Beluga River. The reports of prospectors indicate that the same formation stretches underneath the gravel sheet northeast of the Beluga and occurs on the flanks of the Susitna highland. These are probably the rocks which the prospectors describe as "cement gravels." Some gold of the placers of the Yentna district has been found resting on similar rocks.

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[1] Brooks, A. H. The Mount McKinley region: U. S. Geol. Survey Prof. Paper 70, pp. 95, 143, pl. 9, 1911.

Back of Tyonek and near Beluga River the Tertiary rocks are for the most part deeply buried in terrace gravels. The margin of this gravel sheet is marked by a scarp which skirts the shores of Cook Inlet from Tyonek to Beluga River, then trends inland. This scarp has not been traced very far beyond Beluga River, but probably crosses Theodore River about 10 miles from the coast. The upper gravels of Lewis River, referred to below, are probably an easterly extension of the same formation.

The following notes on Lewis River are based largely on information furnished by Mr. Samuel E. Wagner. In 1916 the mining developments were, so far as known, all on Lewis River, which flows into Cook Inlet a few miles west of the Susitna River delta.[1] Lewis River is reported to be about 25 miles in length and to include auriferous gravels along about 5 miles of its course. The mouth of the river can easily be reached by launch from Anchorage, only 40 miles distant. Good timber is abundant in this region.

Lewis River is described as heading in a broad, flat basin about 2 miles wide. Here the country rock is reported to be granite. Below this basin the walls converge and mark a well-defined valley which continues for 4 or 5 miles downstream to the point where the river debouches on an alluvial coastal plain, 10 miles from Cook Inlet. The developed claims lie chiefly in the constricted portion of the valley, and here the river is said to have sufficient grade for placer mining.

In 1916 some drilling for placer ground was done near the edge of the flats where Lewis River reaches the plain. Here 36 holes are reported to have been sunk and bedrock to have been reached at a depth of 12 to 22 feet. The character of the bedrock was not learned. For about 2 miles above the flats this bedrock of the river is said to be "cement gravel," which is probably a Tertiary gravel. In this stretch of the river the gravels are said to range in thickness from more than 15 feet near the flats to about 3 feet 2 miles above. On the Daisy and Bessie claims a small hydraulic plant was installed in 1916, water being provided by a ditch about 1,500 feet long. The gold here mined is coarse and rough, one $3 nugget having been found. Above the belt of conglomerate the valley walls are made up of granite, but bedrock has not been reached by mining operations. On the Granite claim, in this granite belt, an open cut was made to a depth of 18 feet but did not reach bedrock. The upper part of the alluvium is coarse gravel, and below is finer material in which good prospects are said to have been found. The gold is fine but angular, and the large pieces have quartz attached to them. The owner of the claims believes that there is a deep channel here and is directing development work toward its discovery. The same general conditions are believed to hold in the remainder of the gold-bearing zone, which has been traced only to the upper basin already mentioned.

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[1] It is not certain that the river marked as Lewis on official maps is the one so named by the prospectors. It may be that the "Lewis River" of the prospectors is the one called "Theodore River" on the maps. See Topographic reconnaissance map of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pl. 2, 1915.

Development work was done in 1916 on about eight placer mines on Lewis River, besides the drilling on the flats. About 30 men were engaged in this work. Most of the development has not gone beyond the prospecting stage, but over $2,000 worth of gold was won incidentally to these operations. The gold is reported to have a value of $18.66 an ounce.

ANCHORAGE-MATANUSKA REGION.

The only productive mines in the Matanuska region during 1916 were the two small coal mines referred to on page 25. A low-grade deposit of chalcopyrite ore has been found on Moose Creek, about 8 or 9 miles from Matanuska, and similar deposits are said to have been found on King River. It has long been known that there was some mineralization along the margin of the granodiorite mass of the Talkeetna Mountains. It would therefore not be surprising if metalliferous lodes were found in this region. This mineralized area has a similar geologic position to that of the lodes of the Willow Creek district. In the Willow Creek area, however, the chief metal of the ores is gold, while in the Talkeetna area it is copper. There is an unconfirmed report of the finding of some tin ore in the basin of Eklutna River, tributary to the upper part of Knik Arm.

WILLOW CREEK DISTRICT.

There was much activity in the Willow Creek lode district during 1916. Developments there were stimulated both by the success achieved in several mining ventures and by the fact that railway construction in 1917 will make the district readily accessible from the town of Anchorage.

Though much more development work was done than in the preceding year, most of the mines had not reached a productive basis. Four lode mines were operated in 1916 and milled 12,180 tons of ore, yielding $299,183 worth of gold and $966 worth of silver. About 150 men were employed in these mines. A little gold was also recovered in 1916 from placers of Willow Creek incidentally to the annual assessment work. In 1915 three lode mines were operated in the Willow Creek district and produced 6,717 tons of ore from which gold was recovered to the value of $247,267.

The Alaska Free Gold mine was operated from May to October. It is reported that ore was found on the Tomboy lode 100 feet below the old workings. The property is equipped with two Chilean mills, two crushers, and a cyanide plant. Water power is used, supplemented by a gasoline engine.

The Independence mine was operated from May to September. Underground development during the year consisted principally in the driving of a 300-foot adit designed to crosscut the ore body in depth and a new tram built to connect the lower level with the mill. The equipment consists of a Chilean mill, a crusher, and concentrating tables.

The Gold Bullion mine, equipped with a 12-stamp mill, concentrating tables, and cyanide plant, was operated from June to October. About 1,500 feet of underground work was done during 1915. This consisted chiefly of adits, crosscuts, and raises located for the purpose of blocking out ore.

An adit was driven on the Mabel mine for a distance of 150 feet, and some ore was treated in a small Chilean mill installed on the property in 1915. It is reported that a molybdenite-bearing vein was discovered near the Mabel claim in 1916.

The Talkeetna Mining Co., successor to the Matanuska Mining Co., in 1916 drove four adits on its property, aggregating about 140 feet in length, besides tracing the lode by open cuts. Preparations were made for installing a Chilean mill in 1917. In addition to that recorded above considerable prospecting and development work, the details of which are lacking at this writing, was done in the Willow Creek district.

YENTNA DISTRICT.

The most important event of the year's mining in the Yentna placer district was the installation of a dredge on Cache Creek. The material for this dredge was brought up Susitna and Yentna rivers to McDougal in the fall of 1915 and then sledded to Cache Creek during the following winter. The dredge[1] was operated from July 9 to October 1. It is equipped with 65 close-connected buckets, each having a capacity of 7 cubic feet, and, as thus equipped, can dig 30 feet below the water line. The dredge has a daily capacity of 3,000 cubic yards, but in view of the shallowness of the ground, the average depth being only 6 feet, it is expected by the management that an average of only 2,000 cubic yards will be attained. The dredge is equipped with a 250-horsepower tubular boiler. A peculiar feature of the dredge is that fuel is provided from a lignitic coal bed near by. This is the only dredge in Alaska which utilizes local coal. Some boulders have been encountered in the gravels but have not seriously interfered with mining operations. Two companies were engaged in drilling dredging ground on Kahiltna River. The discovery of platinum in the Kahiltna is mentioned on page 23.

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[1] Smith, Sumner, The Cache Creek dredge: Min. and Sci. Press, vol. 113, pp. 908-909, 1916.

Owing to a shortage of water in the early part of the season placer mining was not as extensive as in some previous years. Complete returns are not yet available, but it is estimated that about 20 mines were operated for at least part of the summer and that these employed about 85 men and recovered gold to the value of about $60,000. The operated mines were pretty well scattered over the entire district and included a number of small hydraulic plants. A hydraulic plant was installed on lower Nugget Creek in 1916. Claims on both Peters and Spencer creeks were prospected during the summer with a view to installing hydraulic plants.

UPPER SUSITNA BASIN.

About 30 men were engaged in prospecting in the Broad Pass region. Discoveries of large bodies of low-grade ores have been reported, but these reports have not been verified through field examination by Survey geologists. The ores are said to include gold, silver, lead, and copper. It is also reported that gold and copper bearing veins have been discovered in the Talkeetna River basin near the Sheep Creek basin. One large hydraulic plant was operated on Valdez Creek, and a smaller one on its tributary Lucky Gulch. There was also some systematic prospecting on White Creek, a tributary of Valdez Creek.

SOUTHWESTERN ALASKA.

Some developments were continued on the copper deposits of the Iliamna region, notably on the McNeil claims, near Kamishak Bay from which a test shipment of ore was made, but as yet there are no producing mines in this field. A small cyaniding plant has been installed and operated to handle the old tailings of the Apollo mine on Unga Island.

It is reported that auriferous quartz was discovered in 1916 on the south side of Unga Island about 3 miles from the old Apollo mine. The ledges are said to be very wide and to carry gold. Specimens from one of these ledges, received through the courtesy of Mr. James R. Hayden, indicate that it is made up of sheared volcanic rock, which has been mineralized. The information at hand therefore indicates that the deposit is a shear zone in the andesite lavas that form the country rock of this part of Unga Island.[1] Silicification and some mineralization have apparently taken place along such a shear zone or system of shear zones. This occurrence is not unlike that of the Apollo mine, which has been described as a "reticulated vein or zone of fracture in a country rock of andesite or dacite."[1] At the Apollo mine, however, there is a well-defined ore shoot of high tenor. The Apollo ore, moreover, carries much galena, whereas galena is reported not to occur in the newly discovered lodes. The current reports indicate that at least three different parallel lodes have been found at this locality.

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[1] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pl. 8, 1911.

Some auriferous gravels were found in 1916 on the east side of Alaska Peninsula, between Cold and Katmai bays. It appears that the placers were found on only one creek, and the output was only a few hundred dollars. The discovery, so far as known, is of importance only in marking a new locality where auriferous mineralization has taken place. Beach placer mining was continued on Kodiak and Popof islands.

YUKON BASIN.

GENERAL FEATURES.

The value of the placer-gold output of the Alaska Yukon districts in 1916 is estimated to have been $7,550,000, compared with $7,050,000 in 1915. About 390 placer mines were operated in the summer of 1916, giving employment to about 2,560 men, and about 150 placer mines were operated in the winter, employing about 680 men. Several small lode mines were productive in the Yukon basin in 1916, all in the Fairbanks district. The following table gives the estimated gold output of the principal Yukon placer camps:

Estimated value of gold production from placers of Yukon basin, 1916.

Iditarod	$1,950,000
Fairbanks	1,800,000
Ruby	850,000
Hot Springs	800,000
Tolovana	700,000
Koyukuk	320,000
Marshall	$320,000
Circle	300,000
All others	510,000
	7,550,000

The Yukon placer mines also produced $29,189 worth of silver in 1916. The above figures do not include the output of the lode mines, which in 1916 produced gold and silver to the value of $39,478. There was also a small output of tin from the Hot Springs district, and considerable tungsten and antimony ore was shipped from the Fairbanks district. (See pp. 20–21.) The total value of the entire mineral production from the Alaska Yukon in 1916 was $7,839,757; that of 1915 was $7,423,352. Since mining began in 1880 the Alaska Yukon has produced minerals to the value of $104,050,000, most of which has been derived from the gold placers.

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[1] Idem, p. 126.

FAIRBANKS DISTRICT.

Placer-gold mining began in the Fairbanks district in 1903. The first productive auriferous lode mining was in 1910. Antimony was mined in 1915 and 1916 and tungsten mining began in 1916. Some silver has been won, incidentally to gold mining, and in 1916 a little silver-bearing galena ore was produced. The total value of the entire mineral output up to the close of 1916 is $68,993,000. Much the larger part of this amount represents the value of the placer gold produced, which is shown by years in the subjoined table. In addition to the actual production of the district, about $1,000,000 worth of gold mined in tributary areas annually passes through Fairbanks.

Placer gold and silver produced in the Fairbanks district, 1903–1916.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1903	1,935.00	$40,000	348	$188
1904	29,025.00	600,000	5,225	2,821
1905	290,250.00	6,000,000	52,245	28,212
1906	435,375.00	9,000,000	78,367	42,318
1907	387,000.00	8,000,000	69,660	37,616
1908	445,050.00	9,200,000	79,909	43,151
1909	466,818.75	9,650,000	84,027	45,375
1910	295,087.50	6,100,000	53,116	28,683
1911	217,687.50	4,500,000	52,245	27,690
1912	200,756.25	4,150,000	48,182	29,632
1913	159,637.50	3,300,000	20,274	12,245
1914	120,937.50	2,500,000	29,024	16,050
1915	118,518.75	2,450,000	28,444	14,421
1916	87,075.00	1,800,000	11,058	7,276
	3;255,153.75	67,290,000	612,124	335,678

The data relating to the source of the gold by creeks are not very accurate. An attempt has been made in the following table, however, to distribute the total placer-gold production of the Fairbanks district by the creeks on which the mines are located:

Approximate distribution of gold produced in Fairbanks district, 1903–1916.

Cleary Creek and tributaries	$22,620,000
Goldstream Creek and tributaries	13,500.000
Ester Creek and tributaries	10,960,000
Dome Creek and tributaries	7,770,000
Fairbanks Creek and tributaries	7,250,000
Vault Creek and tributaries	2,570,000
Little Eldorado Creek	1,980,000
All other creeks	640,000
	67,290,000

Both gold placer and lode production are on the decline in the Fairbanks district. Now that railroad connection with tidewater is assured, mine owners have generally adopted the policy of waiting until mining costs are reduced before embarking in any large enterprises. Besides lowering freight rates the railroad will bring in the Nenana lignitic coal and thus afford a cheap fuel, which is all-important in the mining industry because the price of wood is now almost prohibitive to any operations except the mining of rich placers. Though some discoveries of rich gravels are made year by year, the days of bonanza mining in the district will soon be almost a thing of the past.

Some work was done in 1916 preparatory to larger mining enterprises, but there are as yet but few of these projects, and these will take considerable time to reach a productive basis. Therefore the immediate outlook is for a further decline in gold production. This decline, however, will be only temporary, for there are in the district large reserves of auriferous gravels that can be profitably mined by the use of proper equipment.

There are few data for determining the placer-gold reserves of the Fairbanks district. Prindle and Katz[1] in 1908 made a rough estimate of the placer-gold reserves. They considered that of the then known creek gravels deposits aggregating about 75 miles were gold placers that could be profitably exploited. A moderate estimate indicates that these placers contained gold to the value of about $100,000,000. As about $67,000,000 worth of gold has been mined up to the present time, this would now leave only about $33,000,000 in the placers. Though some allowance was made in this estimate for placers that could not be mined under conditions existing in 1908, there was no attempt to determine the ultimate recovery of gold from the placers of the Fairbanks district. In 1908 the average recovery of gold per cubic yard in the Fairbanks district was $5.53. At that time much the larger part of the mining was done by underground methods, the most expensive form of mining. In 1914 the average gold recovery per cubic yard in the district was $3.31;[2] in 1916 it was about $3. This reduction in recovery shows that methods have been developed to work at a profit placers which in 1908 had no commercial value. Cheaper fuel will permit still further reductions in operating costs. More important, however, to the future of the district will be the introduction of mining plants, notably power excavators of some kind and probably dredges. The possibilities of this form of mining are illustrated by the history of placer mining in Seward Peninsula. There the average gold recovery per cubic yard for the nine years of mining ending with 1906 was about $5.95 a cubic yard.[3] Since then the use of dredges has reduced the average recovery to about 53 cents a cubic yard (1916).

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[1] Prindle, L. M., and Katz, F. J., Geology of the Fairbanks district: U. S. Geol. Survey Bull. 525, pp. 114-115, 1913.

[2] Brooks, A. H., The future of gold-placer mining in Alaska: U. S. Geol. Survey Bull. 622, p. 75, 1915.

[3] Brooks, A. H., The gold placers of parts of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 328, p. 136, 1908.

It is not intended to imply that placer mining at Fairbanks, where much of the placer ground is deep and where nearly all the gravels are permanently frozen, can be done at as low a cost as in Seward Peninsula. But if placers carrying only $1 a cubic yard can be profitably mined the gold reserves of the Fairbanks district have a value of probably several times the $33,000,000 which has been cited above as the value of the gold content of the gravels that can be mined under present conditions. Therefore, though the prospect of immediately increasing the Fairbanks production of placer gold is not very encouraging, yet there can be no question that the district will in time again increase its output and that mining will continue for many years after the exhaustion of the rich deposits now being worked. There is no reason for pessimism in regard to the placer-mining industry of the Fairbanks district, yet it is high time that systematic prospecting of the extensive deposits of low-grade auriferous gravels was undertaken.

It is even more difficult to forecast the future of the gold-lode mining industry of the Fairbanks district. Auriferous mineralization has occurred over a considerable area. A number of small rich gold veins have been worked at a profit. A much larger number of lodes have been found on which comparatively little development work has been done, and some of them are certainly worthy of careful prospecting. There is no reason to believe that any greater irregularity in distribution of value will be found at greater depths than has already been found below the zone of oxidation, which in most places in the district is not many feet deep. There are some larger zones of mineralization which may prove to be workable at a profit if developed on an extensive scale. This can only be determined by a more systematic prospecting than has yet been undertaken. These facts indicate that under the improved industrial conditions which will be brought about by the construction of the railroad a gold-lode mining industry will be developed.

During the last two years considerable antimony (stibnite) and tungsten (scheelite) ore has been mined and shipped. This has been possible because of the great demand for and value of these minerals caused by the present industrial conditions. It remains to be determined whether these ores can compete with others in the market under normal conditions. It is possible that if large deposits are opened under the present stimulus profitable mining might be continued under a normal market after railroad communication becomes available.

Mining operations in the Fairbanks district during 1916 included placer mining on a large scale and a little gold-lode mining, besides the production of considerable antimony ore (stibnite), tungsten ore (scheelite), and a little galena. The value of the total mineral output from the district, including the silver won incidentally to gold mining in 1916, is about $2,040,800. An important event of the year was the decision of the Bureau of Mines to establish a mine experiment station at Fairbanks.

It is estimated that 115 placer mines were operated in the Fairbanks district during 1916. About 50 were working during the winter. About 650 men were employed in the summer and 250 in the winter. The best information available indicates that in all 600,000 cubic yards of gravel was sluiced. The largest single operation was that of the dredge on Fairbanks Creek, the only one operating in the district. The producing creeks, arranged in order of size of total production of their mines are Goldstream and its tributaries, including Pedro and Gilmore, Cleary and tributaries, Fairbanks and tributaries, Ester and Gold Hill, Dome, Eldorado, and Vault. About 80 deep mines were operated during the year, of which 25 were on Cleary Creek and Chatanika Flats. The large open-cut mines were for the most part equipped with steam scrapers, a method of mining which has proved very economical. There was a relative increase in the number of small plants compared with previous years. A few years ago deep mines that employed 30 to 50 men were not uncommon, and the average number was about 10. In 1916 but few deep mines employed more than 20 men, and the average number was less than 6. An average of 7 men were employed in open-cut mines during 1916.

There was but little gold-lode mining in the Fairbanks district during 1916. Probably the most significant event was the beginning of systematic large-scale prospecting of some lodes in the Eva Creek region. Seven lode mines made a small production; 1,111 short tons of ore was hoisted, and the value of the gold recovered was $39,376. Details regarding lode mining are presented by Mr. Mertie in another chapter of this report. The following table sets forth the Fairbanks lode production by years since this form of mining first began:

Lode gold and silver produced in the Fairbanks district, 1910–1916.

Year.	Crude ore (tons).	Gold.		Silver.	
		Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1910	148	841.19	$17,339	106	$57
1911	875	3,103.02	64,145	582	308
1912	4,708	9,416.54	194,657	1,578	971
1913	12,237	16,904.98	349,457	4,124	2,491
1914	6,526	10,904.75	225,421	2,209	1,222
1915	5,845	10,534.91	217,776	1,796	910
1916	1,111	1,904.81	39,376	140	92
	31,450	53,610.20	1,108,221	10,535	6,051

Scheelite, a tungsten ore, was first found at Fairbanks in the fall of 1915 near the head of Gilmore Creek. Development work was at once started, and some shipments of ore were made by parcel post during the winter of 1915–16. Meanwhile, other occurrences of scheelite had been found, and in the summer of 1916 an output from three different mines was obtained and some development work done on others. A part of the ore was shipped to Tacoma for concentration, but most of it was concentrated in one of the local mills. The total production, calculated in concentrates with a content of 60 per cent tungsten or better, is estimated to be 38,780 pounds. It is difficult to place a value on this product, but it seems that the producer received about $63,000 for the entire output.

The decline in the price of antimony during the spring and summer of 1916 led to the closing of most of the antimony mines in the Fairbanks district and discouraged further prospecting for such ore. Five mines were closed by August. One mine however, continued to operate during the summer. The production of antimony for the Fairbanks district is estimated to be 1,390 tons, and the tenor of the ore ranges from 55 to 65 per cent of antimony. For this the producer is estimated to have received about $130,000. Details regarding tungsten and antimony mining are presented by Mr. Mertie elsewhere in this report.

CHISANA DISTRICT.

A shortage of water in the Chisana district during the summer of 1916 hampered the sluicing, and hence the output of gold had a value of only $40,000, compared with $160,000 for the output of 1915. Twelve mines were operated during the summer of 1916, and two during the preceding winter, employing in summer about 40 men. The entire number of men engaged in both prospecting and mining was about 75. Eight of the producing mines are on Bonanza Creek; the others are on Big Eldorado, Little Eldorado, and Gold Run creeks. A hydraulic plant was installed on Bonanza Creek but was unable to operate on account of lack of water. The two deep mines worked in the winter are located on Skookum Gulch and Gold Run. The development of the district is much hampered by the fact that no trail has been built from McCarty, on the Copper River Railroad, the route usually followed by the miners.

FORTYMILE AND EAGLE DISTRICTS.

Mining operations in both the Fortymile and Eagle districts are chiefly on a small scale. This is shown by the fact that about 50 different mines were operated in this field during 1916, which produced gold to the value of about $75,000 and employed 115 men. During the winter about 15 deep mines were worked in the Fortymile district and one on Barney Creek, in the Eagle district. Probably the most important event of the year was the finding of gold placers in the bench deposits of Fortymile River near the mouth of Steel Creek.

In the Eagle district a small hydraulic plant was installed on Alder Creek and preparations were made for similar installations on Crooked and Fourth of July creeks. Some systematic prospecting was also done by crosscutting on Seventymile River near Fox Creek and also between the falls and Barney Creek.

TOLOVANA DISTRICT.

The value of the gold produced in 1916 from the Tolovana district was about $700,000; the output in 1915 was worth $80,000. Most of this gold came from the deep placers on Livengood Creek, where about 15 mines were operated during the winter and 21 during the summer. One deep mine was operated on Myrtle Creek during the summer. About eight open-cut mines were operated on Olive, Ruth, Lillian, and Gertrude creeks. About 125 men were employed in mining during the winter and 360 during the summer. It is estimated that 130,000 cubic yards of gravel was sluiced during 1916. There was a little mining and more prospecting in the Tatalina region, also in the Tolovana district. Preparations were made for drilling some placers in this part of the district with a view of installing a dredge. A more detailed description of the Tolovana district, by Mr. Mertie, will be found in another part of this report.

CIRCLE PRECINCT.

The Circle precinct includes the Birch Creek district and the placers of Woodchopper, Beaver, and other creeks. About 27 small deep mines were worked in the winter, employing 60 men, and 40 during the summer, employing 150 men. These mines produced gold to the value of about $300,000. In 1915 about 50 mines were worked, employing 200 men and producing about $230,000. These figures show the general tendency toward operations on a larger scale. A shipment of wolframite, obtained from the placers of Deadwood creek, was made in 1916.

The largest single plant was the dredge on Mammoth Creek, which was operated for 96 days. Hydraulic plants were operated on Mastodon, Eagle, and Switch creeks throughout the open season. A new hydraulic plant was installed on Butte Creek but was operated only a short time on account of scarcity of water. Preparations were made for installing a hydraulic plant on Independence Creek. The largest number of operations were on Deadwood Creek, but these were chiefly on a small scale. Many of these mines were worked in the winter. Some prospecting was done on the lower part of Boulder Creek, a tributary of Crooked Creek. Here some good prospects are reported to have been found in the benches.

RAMPART DISTRICT.

During 1916 four mines were worked in the Rampart district in the winter, employing about 12 men, and eight in the summer, employing about 28 men. The value of the total gold output was about $40,000. This includes the production of Quail Creek, formerly in the Rampart district but now in the Tolovana district. Preparations were made for the installation of a hydraulic plant on Hunter Creek. The largest gold production came from Little Minook and Hunter creeks.

HOT SPRINGS DISTRICT.

The Hot Springs placer mines are estimated to have produced gold to the value of $800,000 in 1916 and $610,000 in 1915. Most of the mines were operated on a large scale, the total number operated being 16, and these employed 320 men. There was no productive work during the winter, but about 30 men were engaged in prospecting and development work. Much the largest operations were on Woodchopper Creek, where three plants were working during the summer. The placer here occupies a deep channel between 150 and 200 feet below the surface. The mines of the Eureka Creek region, which included two hydraulic plants, were the second largest producers. Here five mines were operated, employing some 30 men. Two mines, employing about 40 men, were operated in the Sullivan Creek region. On American Creek three mines were operated, employing 25 men. Some mining was also done on Cache and Idaho creeks. New discoveries of placer ground were made on Big and Little Boulder creeks, tributary to Fish Lake. This ground is said to be shallow, and though the gold content is not high, the owners believe that it can be profitably mined by hydraulic means. Considerable placer tin was recovered incidentally to gold mining.

RUBY DISTRICT.

The value of the gold produced in the Ruby district in 1916 is estimated to be $850,000. A small shipment of tin was made from the gold-bearing gravels of Midnight Creek, which are said to carry also some tungsten. Forty mines, employing about 325 men, were operated during the summer and about a dozen, employing about 40 men, during the previous winter. Most of the mining was of deep gravels by underground methods. The completion of a dredge on Greenstone Creek was the most important event of the year. It started operating late in July. As in 1915, the deep mines yielding the largest output were those on Long, Flat, and Poorman creeks and their tributaries. Four plants were operated on Spruce Creek, which is now an important producer of placer gold. Mining was also started in a small way on Fourth of July Creek.

In addition to those mentioned above there are also productive mines on Midnight, Birch, Elk, Swift, Tamarack, Timber, and Tenderfoot creeks and Bearpup Gulch. Gold was discovered in 1916 on the benches of Poorman Creek. A new type of prospecting drill mounted on a caterpillar tractor base was taken to Long in September for prospecting on Long and Basin creeks. Considerable work was done on the wagon road leading from Ruby to Long.

INNOKO DISTRICT.

It is estimated that the mines of the Innoko district produced gold to the value of $220,000 in 1916, compared with $190,000 for the output of 1915. About 35 mines were worked in the summer, employing about 140 men, and 15 in the winter, employing 30 men. The mines of Yankee Creek had the largest output and those of Gaines Creek second. The output of the mines on Little, Spruce, and Ophir creeks was about the same. Two steam scrapers were worked on Gaines Creek, two on Spruce Creek, and one on Ophir Creek. Prospecting was done on Yankee Creek for dredging ground. A new deposit of placer gold was found on a bench of Gaines Creek near the mouth of Little Creek. Fifteen small deep mines were operated on Little and Ophir creeks during the winter. The value of the total winter production was about $40,000.

In March, 1916, gold was discovered about 30 miles from Ophir on Boob Creek, a tributary of Mastodon Creek, which flows into Tolstoi Creek. The gravels are reported to be a few feet thick and covered with about 30 feet of overburden. Near-by shafts show 70 feet of overburden and a much greater thickness of gravel. This discovery created enough excitement to bring several hundred people to the camp. Most of these soon left without any systematic prospecting. Only one small plant is known to have been operated on a productive basis. The geology, so far as known, is favorable to the occurrence of placer ground, and it is not improbable that workable deposits may be found. A little platinum occurs in the Boob Creek placers. (See pp. 23–24.) The settlement of Tolstoi or Cooper has been established at the mouth of Mastodon Creek. At high water small launches can be run up Tolstoi Creek to this settlement, but at low water cargoes are discharged on Dishkakat River, about 2 miles from Cooper.

IDITAROD DISTRICT.

Mining in the Iditarod district in 1916 consisted chiefly, as in the past, in a few large operations. Fifteen placer mines were operated during the summer, but practically no mining was done in the winter. These employed about 400 men and produced gold to the value of $1,950,000; in the preceding year 24 mines were operated and the value of the gold output was $2,050,000. These plants included three dredges, one drag-line excavator, four scrapers, and seven open-cut mines, operated chiefly by hydraulic methods. It is estimated that 1,580,000 cubic yards of gravel was excavated. This enormous yardage is due to the extensive dredging operations of the Yukon Gold Co. on Flat Creek and of Riley & Marston on Otter Creek. A new dredge was installed at the mouth of Black Creek near the end of the mining season. This dredge is of the flume type, has a 60 by 30 foot hull and is equipped with two 60-horsepower semi-Diesel engines. The bucket line is of the closed-link type and the buckets have a capacity of 2½ cubic feet. The Riley & Marston dredge was refitted with two 60-horsepower engines of the semi-Diesel type. As in the past the larger open-cut operations were on the heads of Flat, Happy, and Chicken creeks and near Discovery claim on Otter Creek.

KOYUKUK DISTRICT.

The Koyukuk district, including the placers of Indian River, is estimated to have produced gold to the value of $320,000 in 1916 and $290,000 in 1915. Fourteen mines were operated in the district during the winter, employing about 90 men, and produced gold to the value of about $240,000. A large part of this gold was taken out of a few rich claims on Hammond River and Nolan Creek. During the summer 29 mines were operated, of which 8 were in the Indian River region, employing 80 men. Aside from the output of Hammond River and Nolan Creek the larger part of the production came from Jay, Gold, Myrtle, and Porcupine creeks. Productive mining was also done on Vermont, Birch, California, Minnie, Smith, Emma, and other creeks. Good prospects are reported to have been found on the high bench claims of Nolan Creek. Some new placers were opened on Rye Creek, a tributary of Flat Creek, which flows into Wild River, but their value is still undetermined. There was considerable prospecting on the South Fork, where preparations were made for drilling.

MARSHALL DISTRICT.

In 1916 some rich placers were developed on Willow Creek, in the Marshall district, and as a consequence the value of the gold output rose from $25,000 in 1915 to $320,000 in 1916. This output came from seven mines, which employed about 100 men. Details regarding the mineral resources of the Marshall district are given in another section of this report.

SMALLER YUKON DISTRICTS.

About 10 men were engaged in mining in the Chandalar district on three claims and produced about $9,000. Some new placers are said to have been discovered on Squaw Creek. Developments were continued at the lode mines, but the mill was not operated. There was a little mining in the Hosiana River region, but no discoveries of importance have been made.

The Richardson district, of the Tanana region, in 1916 produced gold to the value of about $80,000. Much of this came from Tenderfoot Creek, where seven mines were operated. There was also some mining on Banner and Buckeye creeks, and a little prospecting on Kenyon Creek, tributary to Healy River. A new locality of auriferous gravels is reported on Michigan and Granite creeks, both of which flow into the South Fork of Goodpaster River. Considerable prospecting was done on these creeks in 1916. The gravel on these creeks is said to be from 12 to 25 feet thick and the gold to be very coarse. One nugget valued at $9 has been found on Michigan Creek.

There were no large mining operations in either the Bonnifield or the Kantishna districts during 1916. About 60 men were engaged in placer mining in the two districts, and some production was made from 29 claims. The value of the total output is estimated to have been about $40,000. There was also some lode development in both districts. Details regarding the mineral resources of these two districts are given elsewhere in this volume.

KUSKOKWIM REGION.

The inadequate mail facilities make it very difficult to obtain statistics from the Kuskokwim region. From such data as are at hand it appears that the value of the gold output in 1916 was about $80,000. This came from as widely separated localities as Candle Creek, tributary to the Takotna, and the Goodnews Bay district. This gold was produced from about 25 mines, employing about 50 men. In addition there were a larger number of men engaged in prospecting and development work, incidentally to which some gold was produced.

There was also some mining of quicksilver ores in the lower Kuskokwim region, but no details have been learned. It is reported that some work was done on three or four quicksilver prospects, besides the continuation of development work at the Parks mine. A new discovery of rich placer ground in the Takotna district is reported, but details in regard to it are lacking at this writing. A dredge was shipped for use on Candle Creek but did not arrive at its destination. It is to be installed in 1917 for use on ground about 30 feet deep. A new area of auriferous gravels is reported to have been found in the Holitna River basin, tributary to the middle Kuskokwim.

In the Aniak River region mining was done on a smaller scale than in the preceding year owing to a shortage of water on Canyon Creek, the principal producer. Plans were made for drilling on Marvel Creek with the view of installing a dredge. A hydraulic plant was installed on New York Creek at about the end of the season. A placer mine was worked on Mary Creek, a tributary of New York Creek. This is the first production on Mary Creek.

Mining was continued in a small way on Butte and Cowcow creeks, in the Goodnews Bay district. A steam scraping plant shipped to this district failed to reach its destination. A promising find of gold was made on Bear Creek, in the Goodnews Bay district.

Gold is widely distributed in the Kuskokwim basin. Although but few rich placers have been found, there appear to be many localities where there are considerable bodies of auriferous gravel that deserve systematic prospecting with the view of installing large plants. Some of this work has been done, but the operators have met with discouraging conditions as regards transportation. The steamer service to the mouth of the river is so irregular and so inadequate as to greatly increase the cost of all installations. These conditions are not as good as they were on the Yukon in the pre-Klondike days. If adequate ocean and river steamer service were available the Kuskokwim camps should make important contributions to the annual gold output of Alaska.

SEWARD PENINSULA.

The mines of Seward Peninsula produced gold to the value of about $2,950,000 in 1916 and $2,900,000 in 1915. The value of tin, tungsten, silver, and coal produced in 1916 was about $170,000; in 1915 it was $84,000. The value of the total gold production since mining began in 1897 is about $74,292,000. Nearly all this gold was taken from placers; up to the present time little has been produced from lodes. Silver, tin, etc., have been produced to the value of about $880,000. This makes the value of the total mineral output of Seward Peninsula to the end of 1916 $75,170,000.

The year 1916 was favorable to placer mining on account of ample water supply. As a consequence there were more mines operated than in 1915. It is estimated that, including the dredges, 148 mines were operated in 1916, compared with 120 in 1915. That many of the operations were on a small scale is made evident by the fact that about 1,000 men were employed in productive mining in 1916, compared with 1,200 in 1915. Twenty-seven gold dredges were operated in 1916, employing 260 men, and handled about 1,870,000 cubic yards of gravel, yielding gold to the value of about $985,000. In 1915 31 gold dredges were operated and handled about 3,000,000 cubic yards of gravel, yielding gold to the value of $1,050,000. These comparisons show that there was a tendency to limit dredge mining to richer gravels this year than in the preceding year. Evidence of this tendency can be expressed more directly by noting that the average gold recovery by dredges per cubic yard was 35 cents in

1915 and 53 cents in 1916. There are still large reserves of auriferous gravels on the peninsula that are believed to be rich enough to warrant exploitation by dredges. Most of the existing companies own but one dredge each, and it appears as if the time were ripe for stronger organizations to enter the field and introduce economies by mining on a large scale.

It is estimated that about 66 deep mines were operated on the peninsula during 1916. Many of these were operated in winter as well as summer. Besides the dredges about 70 open-cut mines, large and small, were in operation during the summer. Mining was done on a larger scale in the Koyuk district than in any previous year. The value of the gold produced in this district in 1915 was only $3,000, while that of the winter output alone in 1916 was $100,000. Complete returns on the summer operations in the Koyuk district are not yet available. In addition to the gold dredges two placer-tin dredges were operated in the York district. Developments were also continued on the Lost River tin-lode mine.

One of the important developments in 1916 was the beginning of the mining of tungsten (scheelite). At several localities the residual material of scheelite-bearing lodes was worked by placer-mining methods. Some scheelite was also recovered incidentally to the mining of placer gold.

Some antimony ore was mined at the Hed & Strang mines, and a part of this was shipped. Work was done on two graphite deposits in the Kigluaik Mountains. Some coal was mined at Chicago Creek for local use. Details in regard to mining development on the peninsula are contained in another chapter of this report by Mr. Mertie.

KOBUK REGION.

Placer mining continued in a small way during 1916 in the Kobuk region. Details in regard to it are lacking at this writing, but it is probable that the value of the gold output in 1916 was about the same as in 1915, estimated at $20,000.

MINING DEVELOPMENTS IN THE KETCHIKAN AND WRANGELL MINING DISTRICTS.

By THEODORE CHAPIN.

KETCHIKAN DISTRICT.

INTRODUCTION.

Mining operations in the Ketchikan district were conducted on a much larger scale during 1916 than in the preceding year, as is evident by the large increase in production.

Seven copper mines were in operation, and the output of the larger mines was materially increased. Only two gold-lode mines were operated during a part of the year, but development work was continued on other gold-lode properties and a large quantity of gold was won from ores mined primarily for copper. Items of more than ordinary interest are the recent discovery of a lode of stibnite (antimony) ore, a mineral not known previously to occur in this region in commercial quantity, of lodes in which zinc appears to be the predominant metal, and of platinum and palladium in certain of the copper deposits.

Interest in marble continues. At present production is confined to the quarries of the Vermont Marble Co. at Tokeen, but the district contains large bodies of high-grade marble, whose development awaits the capital necessary for their exploitation. Development work was continued on the barite claims on Lime Point, on Prince of Wales Island, and work was started on the construction of a treatment mill. The location of the known mineral deposits is shown on Plate V.

LODE MINING.

PRODUCTION.

The increase in the production of 1916 over that of 1915 is shown in the subjoined table. The gold and silver produced were derived from both the gold lodes and the gold and silver bearing copper lodes. This increased production was due to the continued demand and high price of copper, which made possible the operation of a number of low-grade properties.

Copper, gold, and silver produced in the Ketchikan mining district in 1915 and 1916.

Year.	Ore mined.	Copper.		Gold.		Silver.		Total value.
		Quantity.	Value.[a]	Quantity.	Value.	Quantity.	Value.[b]	
	Tons.	*Pounds.*		*Fine oz.*		*Fine oz.*		
1915	50,997	1,728,182	$302,431	1,727.38	$35,708	11,666	$5,914	$344,053
1916	76,111	3,526,703	867,569	2,769.61	57,253	19,361	12,640	937,462

[a] Computations based on average price of copper in 1915 ($0.175) and 1916 ($0.246).
[b] Computations based on average price of silver in 1915 ($0.507) and 1916 ($0.658).

PRINCE OF WALES ISLAND.

KASAAN BAY AND VICINITY.

Kasaan Peninsula was again the center of the copper-mining activity of the Ketchikan district, owing in large part to the operations of the Granby Consolidated Mining, Smelting & Power Co. (Ltd.), which operates the Mamie and It mines. The Mamie mine was taken over by the Granby Co. in 1913, and development and improvements were started to put the mine into working condition. The aerial tram, which originally extended to the old smelter only, was rebuilt and extended to the dock in the harbor, where the ore is loaded on barges for shipment to the Granby smelter at Anyox, B. C.

Mining operations consist of stoping the irregular-shaped ore bodies composed of chalcopyrite-bearing magnetite, associated with garnet, epidote, and other contact-metamorphic minerals, formed along the border of intrusive dioritic masses that invade limestone and arenaceous sediments. The Mamie continued operations throughout 1916, employing 55 to 85 men. Underground development work has been carried forward on all the levels, and on the lowest level ore bodies formed along porphyry dikes that cut the magnetite have been located. Considerable surface development work has also been done, with a view to locating new ore bodies. A topographic and geologic map has been completed, a magnetic survey has been made to determine the position of the magnetite bodies, and diamond-drill holes have been put down.

The It mine was worked on about the usual scale, employing 25 men. The ore bodies occur along the contact of intrusive diorite and limestone, and are composed of chalcopyrite, pyrite, and associated metamorphic lime-silicate minerals but contain little magnetite. Development work in 1916 consisted in 5,000 feet of diamond drilling and the extension of drifts and raises on the 275-foot and 350-foot levels, from both of which ore was extracted.

Operations at the Mount Andrew mine were started early in the year and carried forward on a larger scale than usual. The ore

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bodies here are composed of very large masses of copper-bearing magnetite.

The Goodro mine, near the head of Kasaan Bay, was operated, and a number of shipments of ore were made. The ore bodies are in gabbro, and the ore minerals are essentially bornite and chalcocite with lesser amounts of other copper sulphides. The ore also carries considerable gold and traces of platinum and palladium. The ore is sorted by hand and trammed to the wharf, where it is loaded on barges for shipment to the smelter.

The Rush & Brown mine, at the head of Kasaan Bay, was operated throughout the year, and shipments of ore were made. The mine is developed on two lodes, a contact deposit of copper-bearing magnetite and a shear-zone deposit carrying copper sulphides. Both of these deposits have been explored to the 250-foot level by various underground workings. Besides these ore bodies of proved persistence and depth there are also a number of surface outcrops that have not yet been cut by the underground workings. A drift is now being driven along an underground slip on the 200-foot level to cut one of these ore bodies, and surface showings near the ore bins are to be prospected by a stope now being opened from the glory hole on the sublevel above the 100-foot level. An incline now being sunk on the sulphide ore body will be used for a working shaft.

South of Karta Bay and northwest of Twelvemile Arm, including the vicinity of Hollis, is a mineralized area in which gold lodes predominate. The country rock is a complex assemblage of sedimentary and igneous rocks whose relations have not been worked out in detail. The bedded rocks include tuff, breccia, schist, thin beds of limestone, black slate, argillite, and graywacke and are cut by a large boss of quartz diorite and associated porphyritic dikes. The lodes are quartz veins and occur in the intrusive and the bedded volcanic rocks as well as in the sediments.

A number of claims have been located on Granite Mountain, in the quartz diorite. On the Last Chance group development was continued during the summer preparatory to putting in a stamp mill. The Ready Bullion mine and mill, near Hollis, were operated with good success. The mine is developed by three adits driven along the vein and connecting stopes. Development work was continued on the Crackerjack group of claims, adjoining the Ready Bullion, but no production was made. The Dunton mine, on Harris Creek, was not operated in 1916, but some prospecting and ore testing were done.

The Burke and Lang claims were recently located on the north bank of Hollis Cove, about a mile northeast of Hollis. The lode as here exposed by surface stripping is a quartz vein about 20 feet wide, trending N. 70° W., parallel to the strike of the inclosing greenstone tuff country rock. Assessment work consisting of surface stripping was done on the Copper Hill claim, about a mile northwest of Hollis, a short distance from the Ready Bullion tram. The lode occupies a shear zone in greenstone tuff and is composed of a network of chalcopyrite veinlets inclosing sheared rock impregnated with particles of chalcopyrite and stained in places with copper carbonates. Both country rock and lode strike N. 70° W.; the greenstone tuff dips steeply northeast, and the lode apparently dips in the opposite direction.

McLEAN ARM AND MALLARD BAY.

Prospecting and assessment work is being continued on a number of claims on McLean Arm and Mallard Bay. The country rock north of McLean Arm and part of that south of the arm is a medium-grained dioritic rock, evidently a part of the batholith that occupies a large area in the south end of Prince of Wales Island. South of the diorite is a narrow strip of greenstone with associated porphyritic alaskite. The diorite is intrusive into the greenstone. The light-colored porphyries are believed to be intrusive into both greenstone and diorite.

The principal work has been done by Polson & Ickis on a group of claims extending from McLean Arm to Mallard Bay, including mineral claims and a mill site. On the Veta a short adit with drifts and crosscuts has been run, and on the Apex and Adit about 200 feet of underground work has been done, besides a number of surface openings.

The ore deposits occupy shear zones in both the greenstone and its associated porphyritic intrusives. Chalcopyrite is the principal ore mineral, with a little secondary malachite and in places a black coating that is probably chalcocite. The Apex, Adit, and Astor claims cover a mineralized zone that has been traced by surface cuts and underground workings for a distance of 300 feet across its strike. Within this zone are a number of well-defined lodes with intermediate parts which are more or less mineralized.

On the Adit claim an adit has been driven for about 200 feet, exposing two well-defined parallel lodes and an intermediate area with disseminated chalcopyrite. The ore appears to follow very prominent fracture planes with a general trend of N. 20° E. and a southeasterly dip. The mineralization was not confined within these walls but extended into the wall rock. The adit follows one of the lodes for about 50 feet and cuts across to another lode. Above the adit, at an elevation of 550 feet, an open cut has been made on a quartz vein which appears to be the hanging wall of the lode.

On the Veta claim the ore body occurs in the greenstone adjoining the diorite that forms the hanging wall of the lode. The lode strikes N. 45° W. and dips 70° NE. A short tunnel crosscuts the lode and drifts along it for about 20 feet. Adjoining the diorite is about 15 feet of greenstone mineralized with disseminated chalcopyrite.

Below this low-grade ore is about 8 feet of high-grade chalcopyrite ore, which occurs in masses and irregular veins in the greenstone and also associated with quartz veins.

The Spik claim is about a mile west of the Polson & Ickis claims and 2 miles south of the head of McLean Arm. It can be reached by a good trail from a point on McLean Arm half a mile west of the Polson & Ickis mill site. The developments consist of a few open cuts and a short adit. The country rock is greenstone with much intrusive granite. The ore exposed by the open cuts is of very high grade. It consists of bornite, chalcopyrite, and pyrrhotite, occurring in irregular masses in the greenstone.

NICHOLS BAY.

The rocks along the shore line of Nichols Bay are mineralized at a number of places, and several prospects have been located, but little work has been done on them.

Near the mouth of the bay the Feickert claim has been located recently and a little surface stripping done. The country rock is red granite and quartz diorite. The lode is a chalcopyrite-bearing quartz vein about a foot wide. It strikes N. 50° E. and stands about vertical. Development work in 1916 consisted of surface stripping and the construction of a temporary shelter and blacksmith shop.

Another Feickert claim has been located on the east side of the bay a short distance from the head. A trail leads from the cabins on the shore half a mile to the workings. The ore is chalcopyrite-bearing quartz, and the country rock is andesitic greenstone. The lode has been prospected by a shaft and other openings and traced on the surface by open cuts.

The Alice claim, on the east shore of Nichols Bay, was recently relocated by Thornton & Kilpatrick. The country rock is andesitic greenstone with intercalated beds of limestone. The ore is chalcopyrite and occurs in the limestone in irregular bunches and veinlets. Two old shafts on the lode were filled with water at the time of visit and were not accessible for examination.

A short distance north of the Alice claim is another property on which a little work has been done. The country rock is quartzite and siliceous slate interbedded with andesitic greenstone. The beds strike N. 20° E. and stand about vertical. The ore bodies consist of irregular masses of rock strongly impregnated with pyrite. No underground exposures were accessible when the property was visited.

TAH BAY.

Several claims, including the Ranger 1 and 2, have been located recently in a mineralized area on the ridge southwest of Tah Bay, a small cove on the north shore of Hessa Peninsula, on the west coast of Prince of Wales Island. The claims, which are on a low ridge about 200 feet above sea level and a quarter of a mile from the beach, may be reached easily by trail. The country rock consists of greenstone tuff and red and green volcanic breccias and associated graywacke and green grits, which are well exposed along the southwest shore of Tah Bay. In the vicinity of the ore deposits the greenstone is cut by many granite dikes with associated quartz veins. The developments to date consist of one prospect adit about 10 feet long and a number of surface clearings to expose the outcrops. The largest outcrop noted is about 25 feet across and is concealed on all sides by vegetation. It is essentially magnetite, but in places carries considerable chalcopyrite. The numerous outcrops of magnetite cover a larger area, but the workings are as yet too meager to show the size of the ore bodies or the nature and extent of the copper-bearing rock.

HETTA INLET AND CORDOVA BAY.

The principal producer on Hetta Inlet was the Jumbo mine, which was operated throughout the year on a large scale. The mine was leased from the Alaska Industrial Co. in November, 1915, by Charles A. Sulzer and since that time has been operated on this lease. A small sawmill has been erected on the beach south of the ore bunkers and supplies timber for mining and building. It is planned to move the town of Sulzer to the vicinity of the mine wharf.

The Rex and Idela claims, recently located by Jack Smith and William Fox, are on the south slope of Green Monster Mountain at an elevation of 1,700 feet and may be reached by trail from the head of Cholmondeley Sound, a distance of about 5 miles. The developments consist of a number of open cuts and short adits which have exposed a mineralized zone for several hundred feet in an easterly direction. The ore bodies are lenses of chalcopyrite-bearing magnetite associated with masses of garnet-epidote-diopside rock along the contact of the limestone and intrusive quartz diorite. A little malachite also occurs.

On the Rex claim a short adit has been driven into a body of magnetite-chalcopyrite rock inclosed between quartz diorite and limestone. The ore bodies, so far as could be judged by the few surface workings, are contact-metamorphic deposits similar in general character to the deposits on Copper Mountain.

Deposits of zinc ore occur on the ridge about 1½ miles northeast of Sulzer. These deposits were not visited by the writer, and information regarding them was obtained from Mr. W. C. Waters. They occur at an elevation of about 2,000 feet on top of a low ridge that extends westward from Beaver Mountain and divides the drainage of Portage Bay from that of Polk Inlet and Twelvemile Arm. The country rock consists of crystalline limestone, black slate, and quartzite, which strike N. 70° W. and dip 70° NE. The limestone caps the ridge and appears to overlie the other rocks but is stratigraphically lower, its steep dip carrying it below the slate and quartzite. The ore deposits occur in limestone. Specimens of the ore examined by the writer consist essentially of zinc blende with a little galena in a limy matrix.

The Lakeside claim, on the extreme south end of Sukkwan Island, is being developed by P. A. Tucker and Hal Gould. Underground developments in September, 1916, consisted of a vertical shaft 51 feet deep and a crosscut at this level 41 feet in length. The country rock is altered pyroxenite, a basic rock which is intrusive into the greenstone schists and associated schistose sediments. The greenstone schists are bedded tuffs and lava flows of andesitic composition with considerable secondary chlorite, epidote, and calcite. The pyroxenite, a rock originally composed essentially of pyroxene and olivine, has been altered to epidote, calcite, and serpentine. The greenstone schists, the sediments, and the altered pyroxenite are all cut by quartz diorite, a large boss of which occupies the rugged hills of the interior of the island. The schists and sediments strike N. 30° W. and dip southwest at steep angles. The ore deposits occur in strongly mineralized shear zones along the contact of the pyroxenite and the greenstone, for the most part in the altered contact zone of the pyroxenite. Two such shear zones have been cut in the crosscut. One of these, in the southwest end of the crosscut, strikes N. 20° W. parallel to the strike of the country rock, but dips northeasterly. For a width of about 5 feet the pyroxenite is mineralized with disseminated chalcopyrite. The other shear zone is in the northeast end of the crosscut and lies along a vertical fault striking N. 20° W. It incloses about 2 feet of good chalcopyrite ore.

No other development is in progress on Sukkwan Island, but at several places the schists show considerable pyrite mineralization.

Harry Wills, representing the Alaska Tidewater Co., of Seattle, has located copper claims on the long peninsula east of Sukkwan Island, a mile north of Lime Point, and plans active development in the near future. The claims are known as the Teresa and Florence.

WEST COAST.

Developments were continued at the Big Harbor mine, on Trocadero Bay, and a test shipment of ore was made. No notable production has ever been made from this mine, but development work has been in progress since 1908 and several shipments of ore have been made. The property was acquired in 1916 by W. W. Sweet, R. W. Sweet, and N. P. Olson, who have incorporated under the name Southeastern Alaska Copper Corporation.

The ore body is a wide zone of silicified greenstone, within which are shear zones carrying lenses of rich chalcopyrite ore and stringer lodes. The country rock on the footwall of the lode is composed of altered calcareous and arenaceous sediments; on the hanging-wall side it is albite-bearing schist. The lode strikes N. 60° E. and dips 60° NW.

The principal developments to date have been on three claims on the chalcopyrite lenses along the hanging wall of the lode. The ore bodies exposed in the workings on the Northland No. 1 claim were described in detail in a previous report.[1] The developments on the Northland Nos. 2 and 3 claims consist of an adit and a connecting vertical shaft 120 feet deep, from which crosscuts have been extended at 28, 48, and 120 feet below the surface. The shaft for its entire depth is in ore consisting of pyrite and chalcopyrite. An adit 64 feet long connects with the shaft 28 feet below its mouth. This adit and a 10-foot crosscut beyond are all in ore, the lode material consisting of silicified greenstone strongly mineralized with pyrite and chalcopyrite. A 20-foot crosscut on the 48-foot level was for 17 feet in pyrite-chalcopyrite ore and 3 feet in barren rock. On the 120-foot level an 18-foot crosscut shows 11 feet of pyrite-chalcopyrite rock and 7 feet of slightly mineralized rocks, but a drill hole in the face penetrates another body of sulphide rock. The workings at this place, known as the upper workings, appear to be on the same lode as the lower workings, for the ore bodies have been traced more or less continuously from the lower to the upper workings by outcrops of chalcopyrite-bearing rocks. The crosscuts at the upper workings, however, have not cut the hanging wall of the lode, so it would appear that the rich chalcopyrite lenses occurring along the hanging wall have not yet been opened and that the present workings are in the leaner part of the lode. It is planned to continue sinking at the upper workings to a depth of 500 feet and to crosscut every 50 feet. At the lower workings a raise to the surface will be completed and sinking continued to a depth of 250 feet, with crosscuts every 50 feet.

DALL ISLAND.

McLEOD BAY.

A number of claims have been located on McLeod Bay, near the south end of Dall Island. Considerable development work has been done, including three adits and a number of open cuts and shafts besides several substantial buildings. The claims comprise several groups and include the Golden Chariot, Elks Pup, Elk, Daykoo, Delaware, No Name, Virginia, West Virginia, and others. The principal development work has been done on the Golden Chariot, West Virginia, and New York. This property is now controlled by W. D. McLeod and others.

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[1] Chapin, Theodore, Mining developments in southeastern Alaska: U. S. Geol. Survey Bull. 642, pp. 92-93, 1916.

The footwall of the lode is massive crystalline limestone; the hanging wall is crystalline schist. Two well-defined ore bodies occur—a strong vein of quartz ranging in thickness from 40 to 60 feet, and a parallel stringer lode, the two lodes with the intervening impregnated rock forming a mineralized zone from 200 to 600 feet wide. The country rock is crystalline limestone and siliceous schist and quartzite with a little greenstone schist. The beds strike N. 45° W. and dip 30°–45° NE. The quartz vein is the most conspicuous of the ore bodies. It has a general northwest strike, dips northeast, about parallel to the beds, and occupies the contact between the limestone and schist. It has been traced by workings and surface cuts for a number of claim lengths but is best exposed on the Elk claim by two adits and an open cut, which crosscut the vein in three places. Along the hanging wall there is a gouge seam about 3 feet thick, and a number of parallel seams of gouge occur on the hanging wall side of the vein. Gouge also occurs along the footwall. The quartz is rusty and brecciated and breaks down easily under the hammer. The vein is being developed for its gold content. The principal metallic mineral is chalcopyrite, with lesser amounts of pyrite and galena. The very little gold that is visible is believed to occur in association with the sulphides. The stringer lode has not been extensively exploited. Several attempts have been made to open some of the rich stringers within it, but no systematic development of the lode as a whole has been made. On the beach claims on the southwest side of McLeod Bay this lode from the beach to the moss-covered area has a surface width of 400 feet and an actual width of 260 feet. This is a minimum width of the lode at this place, as it probably extends beneath the moss-covered area between the exposed part and the vein. At this place the lode is composed of quartzose schist, carrying several strong veins of quartz and innumerable stringers and gash veins. Both quartz and schist are metallized with chalcopyrite, pyrite, and galena. Particles of free gold occur sparingly, and individual stringers appear to be very rich. The schist is uniformly metallized with particles and tiny stringers of the sulphides.

Attempts have been made to open some of the richer of the individual veins, but this method of mining will not prove satisfactory, for the veins are lenticular in habit and tend to pinch out both laterally and vertically. The lode, owing to its diffused mineralization over so great a width, lends itself much more readily to exploitation on a large scale and should be further investigated with this in view.

The Lucky Strike claim is on the crest of Dall Island, at an elevation of 1,300 feet. It is 3 miles east of the head of Gooseneck Harbor, on the west coast, and 4 or 5 miles west of Sawmill Cove and may be reached by a trail starting from a point about 1¼ miles south of the entrance to Grace Harbor.

The country rock consists of metamorphic schist, limestone schist and thin beds of limestone. The lode where not covered by vegetation appears to be a shear zone in the schist, mineralized with chalcopyrite, pyrite, and much limonitic material. It is cut by stringers of bluish quartz carrying bunches of pure chalcopyrite. The schist strikes east and is nearly vertical; the quartz stringers strike N. 20° E. and dip 60° SE.

COCO HARBOR.

The Silver Star claim is about three-quarters of a mile from the head of Coco Harbor, at an elevation of 1,700 feet. The dominant rocks between the prospect and the beach are crystalline limestone, greenstone schist, and black blocky schists. There are two parallel lodes having a general strike of N. 55° W. and a steep northeast dip, about parallel to the strike and dip of the inclosing limestone beds. The larger lode pinches and swells, ranging in width from a few inches to 2½ feet, and veinlets of the sulphides penetrate the wall rock, increasing in places the width of mineralized rock The visible contents are essentially sphalerite, chalcopyrite, and galena, with a relatively small amount of gangue. The other lode, about 30 feet northeast of this one, is of similar appearance and is composed of sphalerite, chalcopyrite, and galena. Assays made on a sample of this ore body showed notable amounts of gold, silver, zinc, lead. and copper.

The underground workings consist of a 50-foot adit and two drifts. The adit was started on the outcrop of the main lode but apparently drifted away from it. Cabins have been built both at the claim and on the beach, and a good trail leads from the beach to the claim.

The Shellhouse claims are half a mile northwest of the head of Coco Harbor, at an elevation of 350 feet. A good trail leads from the cabin on the beach to the workings, which consist of an adit and a number of open cuts. The principal showings of ore are found in a large open cut above the adit. Samples taken from this open cut consist essentially of pyrrhotite and chalcopyrite.

ANTIMONY LODE ON CAAMANO POINT.

A lode of antimony ore was recently discovered on Caamano Point, the southern extremity of Cleveland Peninsula. The country rock is blue limestone intricately veined with calcite and quartz stringers and apparently interbedded with greenstone. The limestone beds strike N. 60° W. and dip 45° NE. The developments to date consist of a 12-foot shaft, a crosscut, and several open pits besides a blacksmith shop and a short trail to the beach. The principal ore body exposed by the workings is a lode of solid stibnite ore about 3½ feet wide, trending N. 60° W., parallel to the strike of the limestone beds, and standing nearly vertical. Its length is not evident, but parallel to it are smaller bunches of stibnite ore, all occurring in a brown-stained limestone ledge. The ore is composed of bunches of solid stibnite (antimony sulphide) with yellow alteration products along the fractures.

NONMETALLIC PRODUCTS.

MARBLE.

The marble quarry of the Vermont Marble Co. at Tokeen, on Marble Island, was operated on about the usual scale, employing 50 men. Assessment work was continued on the property of the Mission Marble Co., on Orr Island; on the Dickinson and Bell claims, on Carroll Inlet; and on the Marble Heart and associated groups, on the west coast of Dall Island, but no production was made. The marble deposits of southeastern Alaska are described in detail in a forthcoming Survey bulletin.[1]

BARITE.

Development work on the barite deposit on Lime Point, Prince of Wales Island, was continued in 1916 by a small crew of men, and a crushing plant near the Jumbo wharf was in process of construction.

WRANGELL DISTRICT.

WOEWODSKI ISLAND.

The only productive mining in the Wrangell district in 1916 was at the Maid of Mexico mine, on Woewodski Island (fig. 1), from which a small test shipment of ore was made.

The property consists of six claims, comprising the Maid of Mexico, Maid of Mexico South Extension, and Maid of Mexico North Extension Nos. 1, 2, and 3, situated on the border of Spear Lake, about 1½ miles from the coast, at an elevation of 400 feet. This property is being developed on a vein of quartz carrying metallic sulphides and free gold. The country rock is greenstone schist with interbedded black slate cut by dikes of porphyry. The dominant strike is about east, with a steep dip to the south. The vein is about parallel to the inclosing country rock. It strikes from east to N. 60° E. and dips 60°–80° to the south and southeast. It follows the porphyry, in places lying between porphyry and black slate and in places penetrating the porphyry. The vein averages 4½ feet in width in the underground workings, but in the open cuts on the Maid of Mexico North Extension No. 1 it is much larger. Where the vein cuts the porphyry dikes it is wider and more irregular than where it lies between slate and porphyry. The quartz carries sphalerite, galena, pyrite, and chalcopyrite, and in places considerable visible gold. The walls are very clean, and the ore breaks away easily. A small parallel stringer occurs about 50 feet north of the main lode. South of the Maid of Mexico another lode has been cut on the adjoining Maid of Texas group of claims but has not been opened.

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[1] Burchard, E. F., Marble resources of southeastern Alaska: U. S. Geol. Survey Bull. 682 (in preparation).

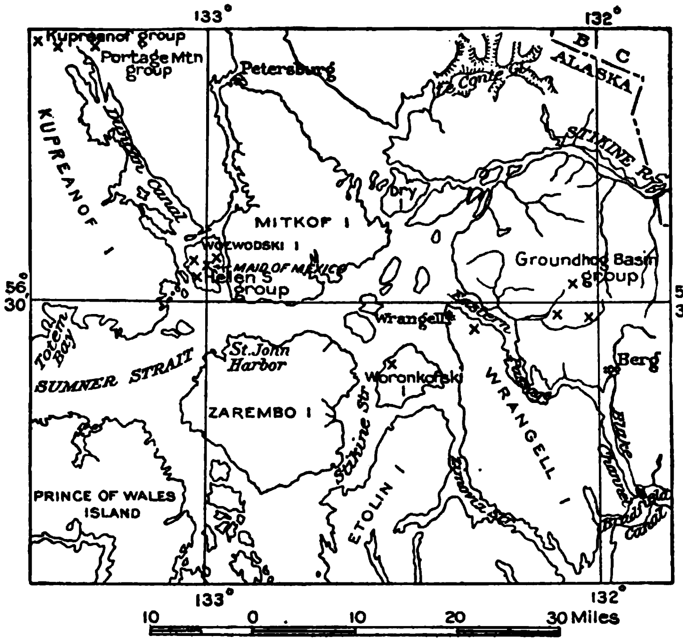


FIGURE 1.—Map showing location of prospects in the vicinity of Wrangell.

The principal work has been done on the Maid of Mexico claim. A crosscut adit 130 feet long cuts the vein 82 feet below the surface, and from this point a drift has been extended 20 feet to the west and 150 feet to the east along the vein. The vein has also been exposed by surface trenching above the adit and drift and also by open pits on the Maid of Mexico North Extension No. 1 and a short adit on the boundary line between the two claims.

MAINLAND.

Assessment work was continued in 1916 at the properties in Ground Hog and Glacier basins. These properties are located 12 miles east of Wrangell, on the mainland, and may be reached by trail from the cabin at the mouth of Mill Creek to the foot of Mill

Lake, by boat across the lake a distance of 3 miles, and by trails from the head of the lake—one trail leading to Glacier Basin and another along Porterfield Creek to Ground Hog Basin—a distance of about 4½ miles from the head of Mill Lake.

The workings are at elevations of about 1,500 to 2,100 feet on the eastern branch of Porterfield Creek. Two ore bodies are being developed, one on each side of the creek. The country rock is argillite and crystalline schist composed essentially of quartz, feldspar, biotite, and hornblende, with accessory garnet, rutile, and pyrite. The general strike is northwest with steep dips northeast. The schist is cut by bodies of porphyritic quartz diorite and dikes of alaskite porphyry, a light-colored rock composed of quartz, orthoclase, and microcline with a little biotite and garnet as accessory minerals.

South of the creek a 15-foot adit crosscuts a lode about 10 feet wide with a hanging wall of schist and a footwall of argillite. The lode carries galena and sphalerite. Along the hanging wall occurs about 20 inches of nearly solid galena. The remainder of the vein contains disseminated galena and sphalerite. Mineralization was less pronounced toward the footwall, where the mineralized rock passes gradually into the slate country rock.

Other workings are on the north side of the creek at an elevation of 2,100 feet and consist of open cuts and two adits, one 12 and one 160 feet in length. The ore bodies are inclosed in dense green crystalline schist cut by many porphyry dikes, along which the lodes have been formed. Both country rock and lodes strike N. 45° W. and dip 63° NE. The best exposures are found in the ong adit, which trends N. 55° E., almost perpendicular to the strike of the country rock and the lode, and which cuts the lode about 70 feet from the portal. The lode as exposed in this opening has a stope length of 30 feet and a width nearly as great. It is diffusely mineralized with sphalerite, galena, and pyrite and contains lenses of nearly solid sulphide ore. Sulphide minerals with accompanying quartz stringers occur in the green schist near the face of the adit. About 100 feet above this opening there are a number of surface cuts and a short adit in the outcrop of the lode, which may be traced along the side of the gulch for a long distance by the wide zone of oxidized rocks.

Development work was continued on the Berg property, on the mainland about 20 miles southeast of Wrangell. It is reported that an adit has been driven for 300 feet, and that work will be resumed in the spring.

LODE MINING IN THE JUNEAU GOLD BELT.

By Henry M. Eakin.

GENERAL SUMMARY.

The progress of the mining industry in the Juneau gold belt (Pls. VI and VII) in 1916 was marked by the continued large-scale operation of most of the established plants, by the construction of larger reduction plants on properties of advanced development, and by the consolidation and enlargement of enterprise in the exploitation of properties hitherto but little developed. Advance was made in determining the extent and character of reserves in the several mines, in more specifically delineating mining difficulties that threaten safety or economy of operation, and in adapting systems of exploration and mining to overcome these difficulties.

The Treadwell group of mines, on Douglas Island, carried on normal operations until August 1, when part of the stamp·mills were shut down to avoid further drawing of ore from beneath settling ground that threatened the safety of the Treadwell, Seven Hundred Foot, and Mexican mines. The other properties continued operating as usual. Other activities on Douglas Island included assessment work on a number of different properties south of the Treadwell group and diamond-drill prospecting on the Tyee, Jersey, and Holman claims, north of Treadwell.

On the mainland near Juneau the Alaska Gastineau and Alaska Juneau properties were in active operation, and development work was in progress on the Alaska Ebner property. Prospecting equivalent to the required assessment work was done on several other properties.

North of Juneau along the gold belt the Eagle River, Jualin, and Kensington enterprises represented the chief activity. The Eagle River and Yankee Basin properties were consolidated early in the year, but no development work beyond the annual assessment work was done. The Jualin mine operated on a moderate scale throughout the year. The new project of developing and equipping the Kensington mine on a 500-ton daily basis was being rapidly executed in 1916, with a view to completion by the spring of 1917.

South of Juneau only small-scale operations were carried on in 1916. The Alaska Gold Belt Co. did a little open-cut prospecting on its claims at the head of Grindstone Creek. At Taku Harbor several claims are still held. At Limestone Inlet Williams & Leak installed a 5-stamp mill and tramway on their property and are reported to have milled some ore. Small operations at Snettisham are also reported. At Windham Bay a consolidation of properties with a view to larger enterprise in development had been made, and engineers were on the ground during the summer making examinations in the interests of prospective investors.

West of Juneau, at Funter Bay, on Admiralty Island, four different properties are held, and assessment work for 1916 is reported to have been done on each. The ground of the Funter Bay Gold Mining Co. has passed into the ownership of a new concern, the Admiralty Alaska Gold Mining Co. The 10-stamp mill on this property, which had been run for several months testing ores, was shut down early in 1916, and development work was suspended pending financial arrangements for enlarged operations.

DOUGLAS ISLAND.

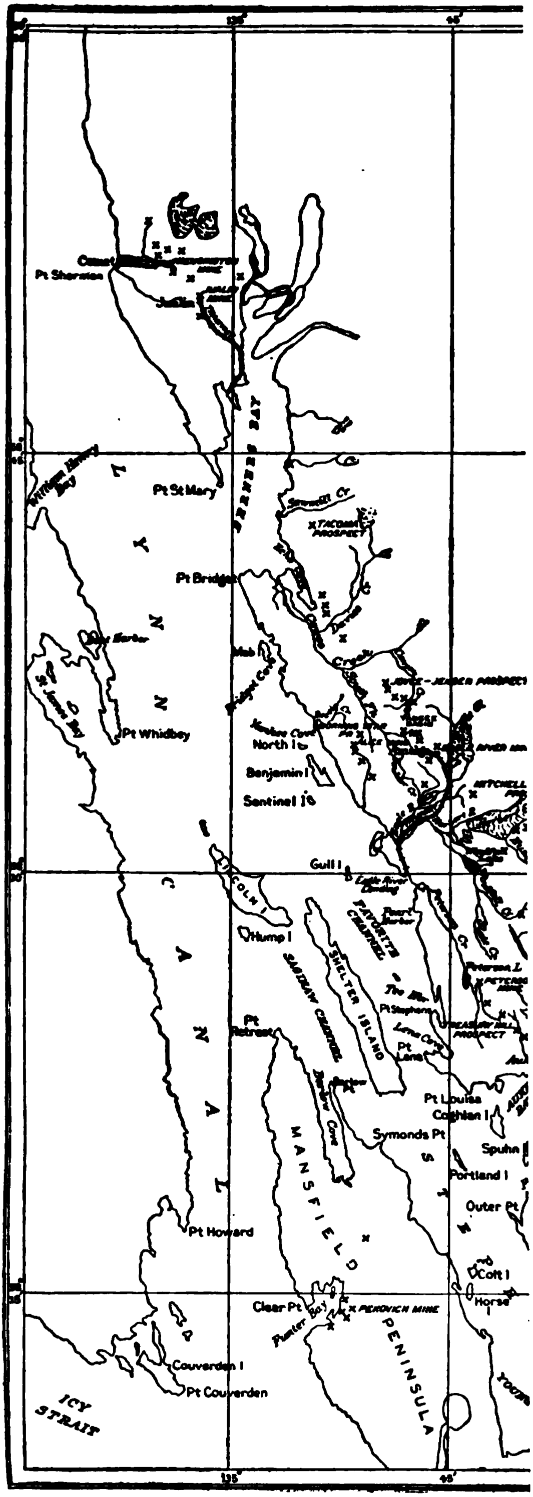
TREADWELL GROUP.

The Treadwell group of mining companies, operating on Douglas Island, carried on mining and milling operations as usual for the first seven months of the year, treating 972,765 tons of ore, an average of 138,966 tons a month. Late in July signs of a subsidence of the hanging wall appeared at the surface near the boundary between the Treadwell and Seven-Hundred Foot claims, over the workings from which the main supply of ore was being drawn. To protect the mines from the dangers of further subsidence the heavy removal of this ore was discontinued August 1 and the 240-stamp mill and half the 300-stamp mill were shut down. The remaining 550 stamps continued normal operations for the rest of the year, treating 422,215 tons, or an average of 84,443 tons monthly, a deficiency of 54,523 tons a month compared with previous operations.

The ore treated during the whole year aggregated 1,394,980 tons, with a total production of $2,466,936 worth of bullion. The following table gives the yearly gold production of the mines from the commencement of operations:

Value of gold produced by Treadwell group of mines, Douglas Island.

1882–1884	$10,902	1896	$1,028,691	1908	$3,124,047
1885	280,479	1897	1,011,693	1909	3,534,871
1886	366,180	1898	1,010,235	1910	3,737,498
1887	476,934	1899	1,611,857	1911	4,983,474
1888	429,889	1900	2,081,840	1912	4,080,300
1889	652,490	1901	1,665,373	1913	3,904,066
1890	160,681	1902	2,223,373	1914	3,743,945
1891	769,765	1903	2,667,914	1915	3,228,066
1892	707,017	1904	2,845,994	1916	2,466,936
1893	694,658	1905	3,146,715		
1894	909,990	1906	3,085,324		64,013,782
1895	852,585	1907	2,520,000		



MAP OF THE NORTHERN P

The subsidence of the surface mentioned above has followed a series of cavings in the upper workings, which began as early as 1913. It has been accompanied by fissuring in the hanging wall and the appearance of a moderate flow of salt water on the 1,600-foot level. These phenomena constitute a menace that must be taken into account in further operations.[1] They affect the rate at which the broken and caved pillar ore can be safely drawn from the upper levels, and perhaps also the amount of this stock that can be finally utilized.

Shrinkage in assay values of the material in the intermediate levels down almost to the 2,100-foot level has caused the abandonment of stopes that otherwise might have supplied the requisite ore for normal milling operations at the present time. As the levels below the 2,100-foot level, where the ore is of higher value, are not yet developed to the productive stage, the mill supply is curtailed to the point indicated by the operations after July 1.

Consideration of the advantage of a unified system of operation of the Treadwell group of mines led to the appointment of a committee to determine a basis of consolidation. The report of this committee, which was submitted July 31, 1916, is in large part reproduced in the Mining and Scientific Press of August 26, 1916. It presents an exhaustive analysis of the past and possible future showing of the different properties, discusses geologic and mining conditions, gives the committee's findings with respect to an equitable basis for consolidation, and proposes a program for future development work. The plan of consolidation appears especially fortunate in view of the difficulties that have arisen to make the expensive work of deeper exploration and development imperative.

The deeper development work was carried on rapidly during the year. The central shaft was completed for the 2,500 and 2,700 foot levels, and the combination shaft was being sunk to the 2,100-foot level. An incline was being sunk in the Mexican mine below the 2,100-foot level. These improvements will combine to give a complete service and ventilating outlet for the stopes on the 2,300, 2,500, and 2,700 foot levels. Diamond drilling below the 2,300-foot level was carried on in the Seven Hundred Foot mine, testing the ore body at least to the 2,700-foot level.

A total of 14,383 feet of development work was done during the year on the entire group. By far the greater amount was done in the Seven Hundred Foot and Ready Bullion mines in developing the ore bodies in the lower levels. In both mines the reserves of ore in sight and broken ore were increased materially. The development work done in the Mexican mine during the first eight months of the year was mainly on the 2,100-foot level. The later work was chiefly on the 2,300-foot level, where preparations for stoping are in progress. In the Treadwell mine development work was practically suspended after August. Earlier in the year considerable work had been done in opening prospective ore bodies on the 2,100 and 2,300 foot levels.

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[1] Further caving and surface subsidence occurred Apr. 21, 1917, resulting in the complete flooding of the Treadwell, Seven Hundred Foot, and Mexican mines with sea water.

MAINLAND.

ALASKA GASTINEAU MINING CO.

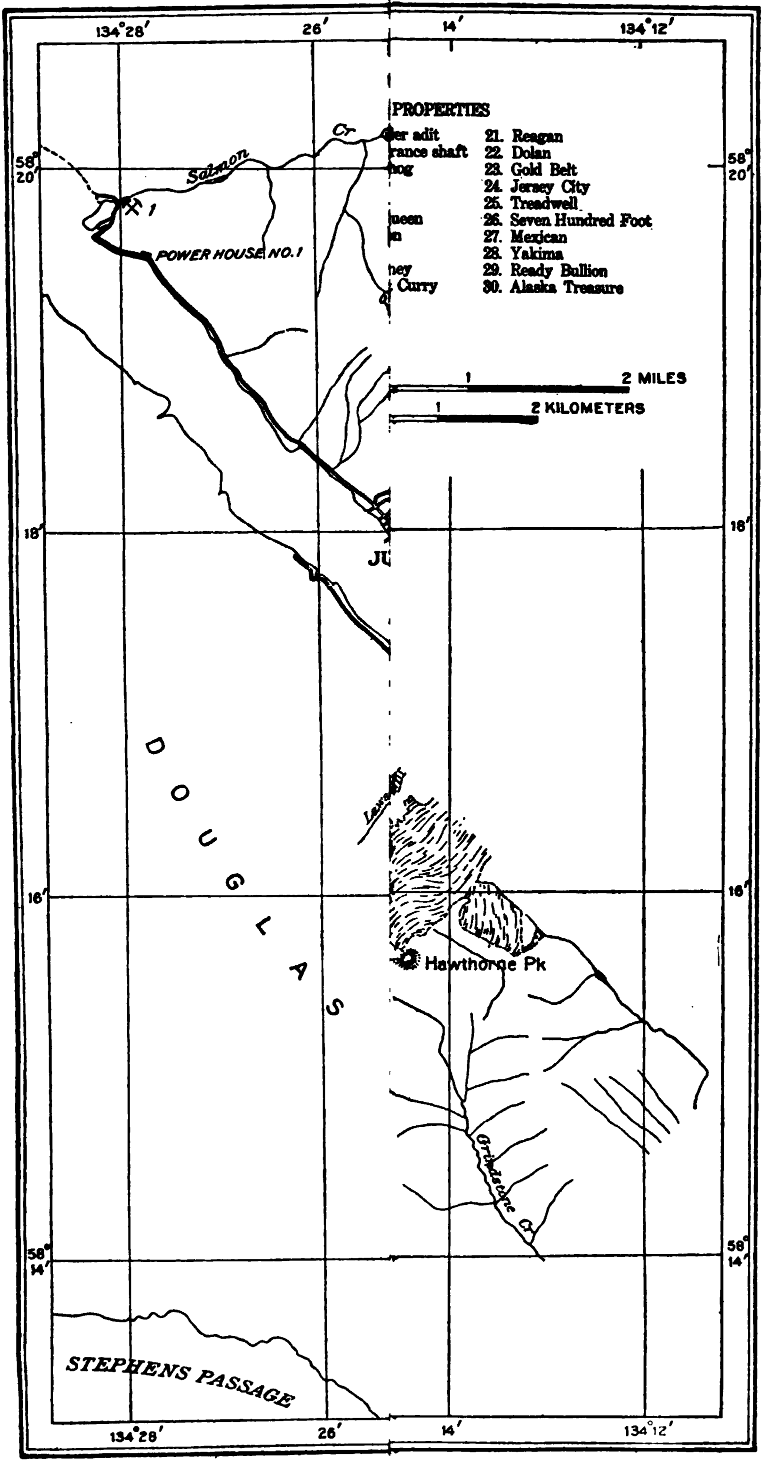
The Alaska Gastineau Mining Co. is the operating company for the Alaska Gold Mines Co., whose properties comprise mineral lands in the Sheep and Gold creek basins, a mill site at the mouth of Sheep Creek, and water-power sites on Salmon and Annex creeks. The development of all these properties was completed in 1915, and operations were carried on throughout 1916 on a 6,000-ton daily basis. The advantages of abundant water power, modern facilities, and simplified methods of extraction have afforded the lowest cost of operation yet achieved in the region.

Owing to the addition of waste from the hanging wall of stopes on the higher levels the average tenor of the ores milled fell below the original estimate, and this has caused misgiving in some quarters regarding the ultimate success of the enterprise. However, the difficulties in the way of selective stoping were being overcome and the tenor of ores showed a gradual improvement month by month, promising soon to reach the desired grade. Smaller stopes than those originally opened are necessary to the production of cleaner ore from the mine. The expense of mining by this method will be greater, but it will be offset by the higher tenor of the ore supplied to the mill. As the levels in the 1,600-foot backing above the main adit are developed to the productive stage the capacity of the mine for producing a proper grade of ore will increase, and without doubt it can be kept equal to that of the present mill for a long period before resort to the reserves below the main adit level must be had.

ALASKA JUNEAU GOLD MINING CO.

The Alaska Juneau Gold Mining Co. proceeded energetically throughout the year with the enlarged development of the mine and the construction of the new 8,000-ton mill.

The main haulageway from mine to mill was widened and equipped throughout with double tracks of 50-pound rails suitable for the traction of 10-ton ore cars, which are to be used exclusively in the enlarged plan of operations. The development of the north ore body was advanced by the completion of undercutting the great stope, 250 feet wide and 700 feet long, with the necessary ore ways, chambers, and gates, for drawing ore along both sides. Work pro-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DOUGLAS
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Hawthorne Pk
Grindstone Cr
58° 14′
STEPHENS PASSAGE

ceeded also in driving raises and powder tunnels in the north ore body above the cut-out area, preparatory to the enforced caving of ore into the stope chamber as drawing proceeds. The south ore body was developed further by driving on working and prospect tunnels and by preparations for stoping selected bodies of proved ore. Although it is expected that the north body can furnish enough ore to supply the rated capacity of the mill, the development achieved on the south ore body makes it possible to supplement the output from this source whenever necessary.

The construction of the mill went ahead steadily during the year. Late in autumn the housing had been completed and the installation of machinery and power plant was well advanced, with the expectation that all would be in readiness for operation early in the spring of 1917. The new mill uses jaw crushers to reduce the ore to 6-inch size, gyratory crushers for reduction to 3-inch size, and ball mills for the first phase of further reduction. Suitable grizzlies are provided so that all undersize is removed ahead of each crushing operation. That part of the ball-mill product going through 10-mesh screens is passed to roughing concentrators; the oversize from these screens is returned to tube mills for regrinding. Classifiers follow the roughers, the fines passing to the finishing tables and the oversize to tube mills for regrinding. Crushing and concentrating are the only operations in the process of ore reduction. The ball-mill practice is patterned closely after that of the Inspiration mill of Arizona.

The 50-stamp pilot mill was run at full capacity most of the year, treating a share of the ore produced in enlarging the mine. Its operation not only served to utilize the ore necessarily produced in drifting and opening stopes but gave practical tests of ores from the different workings and of methods of treatment.

JUALIN MINE.

Operations at the Jualin mine were continued during 1916 on the reduced scale that was adopted at the beginning of the European war, owing to its foreign financial backing. However, there was a gradual increase in the extent of operations during the year, the force of 20 men employed at the start being increased to 65 by the latter part of the summer. The work is progressing on the plan of milling only the ore produced in developing the mine. No stoping is done, as the 10-stamp mill is fully supplied by the ore that is taken from the shafts and drifts that are being driven on the lodes. Although the mine is being developed into a larger producer more slowly than was originally planned, the present operations have the advantage of being self-supporting.

According to Knopf[1] the work done prior to 1910 had developed three parallel veins, 75 feet apart, trending N. 40° W. and dipping 60° NE. to 90°. At that time the workings had reached a depth of 200 feet below the adit level, which is 750 feet above the sea.

The later development work has been directed mainly to the two outside veins. The workings have reached a depth of 310 feet below the adit level, and it is planned to extend them as rapidly as possible to 1,000 feet below the adit.

The northeast vein has an average width of about 7½ feet, and the southwest vein of 5 feet, in the developed areas. The horizontal extent of the ore bodies in each vein is about 400 feet.

The mine waters, which were formerly a hindrance to operations, are now fully controlled. They are collected on the 300-foot level and pumped to the surface at the rate of about 500 gallons a minute. The deeper development is planned so that the mine below the 300-foot level will be entirely dry. Control of the water has been achieved by additions to the pumping and power facilities. About 1,200 horsepower is developed by the hydroelectric plant on Johnson Creek in summer. In winter this is reduced to about 100 horsepower, and additional power is developed by internal-combustion engines as required.

The plans for a larger mill are in abeyance pending a fuller development of the mine in depth. The ores in the upper workings are free-milling, so that ordinary amalgamating methods give a high recovery. In neighboring mines the ores change in character with depth, and a high extraction from the deeper ores is best obtained by flotation methods. The continued development of the mine on a moderate scale will give excellent opportunity for investigating the ores and designing the best equipment for their treatment.

KENSINGTON MINE.

After the consolidation of the Kensington, Bear, and Comet properties by the Hayden-Stone interests the combined development of the Kensington, Eureka, and Johnson lodes by a single adit tunnel was undertaken. This tunnel, known as the Kensington crosscut, was completed for a length of over 5,000 feet in 1914, and additional work was done in drifting on the different lodes. In 1915 only the necessary assessment work was done on the properties, but the reserves that had been developed were investigated further, and plans were matured for future development. These plans contemplated the exploitation of the known reserves with the least practicable expense for equipment and operation. The lodes were to be developed from the Kensington crosscut only; the mill was to be adapted to the use of flotation methods of extraction, with a daily capacity of 500 tons; power was to be developed from streams without artificial water storage, and the scale of operations at different seasons was to be adjusted to the power available from this source—at or above the rated capacity of the plant in summer and at a standstill for a part of the winter. The quarters and other housings on the properties were to be rehabilitated and enlarged as required, and proper rail connections between mine and mill were to be constructed.

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[1] Knopf, Adolph, Geology of the Berners Bay region, Alaska: U. S. Geol. Survey Bull. 446, p. 45, 1911.

Active work on the execution of these plans was deferred until 1916, when it was begun with the expectation of completion early in the spring of 1917. The time schedule adopted for different phases of the work permitted the constant employment of a fairly uniform force of workmen. The wharves, buildings, railways, and trams, hydroelectric plant, milling plant, and concentrate storage and loading plant were to be completed in the order named, and productive operation was to begin May 1, 1917, on the completion of the mill. The progress that was reported late in 1916 indicated that this time schedule was being met.

The Kensington lode, which is fully developed above the adit level, is to furnish the main supply of ore for the first milling operations. The reserves in this part of the lode are said to exceed 500,000 tons. This plan will permit a gradual further exploration and development of the Johnson and Eureka lodes.

The ore is to be stoped by the shrinkage method from levels 200 feet apart, and delivered to the main haulageway in the Kensington crosscut through an ore-way raise in the footwall. Tramways are to deliver the ore from stopes to the ore-way on each level. From the bottom of the ore-way the ore is to be drawn into cars and hauled by storage-battery locomotives to a 250-ton crib outside the portal of the Kensington crosscut. The ore is to be drawn from the crib into 6-ton skips operating on a 3-rail automatic reversible inclined tramway, delivering at a 150-ton hopper at the mill. The hopper bin will feed the ore by gravity to a gyratory crusher, giving a 3-inch product to be elevated to a 500-ton storage bin. Belt conveyors are to carry the ore from the storage bin to ball mills, whose product first goes to equalizing tanks and then to flotation machines. The flotation product is then to be dewatered and loaded directly from the filter to 5-ton cars for haulage to the wharf tipple.

Experimental work in the flotation of the Kensington ores shows that this method of treatment is far superior to the amalgamation process that was formerly used. Extractions of 92 per cent to over 97 per cent have been made, about 4 pounds of oil being used to the ton of pulp. Further experiments with a view of reducing the consumption of oil and power were in progress during 1916.

FUNTER BAY, ADMIRALTY ISLAND.

GEOGRAPHIC FEATURES.

Funter Bay is formed by a reentrant in the east shore line of Chatham Strait about 10 miles south of Point Retreat, the north extremity of Admiralty Island. It is 18 miles directly west of Juneau, but by water routes the distance is over 50 miles. The bay is about a mile wide and 2 miles long. The shore line is irregular, and the bay contains a number of small islands and reefs. There is a clear steamboat passage well into the head of the bay, and it forms an excellent harbor, with favorable sites for docks in many places.

The shore of the bay is marked in most of its extent by low sea cliffs, reaching 10 to 30 feet above sea level, back of which lie broad terraced tracts 50 to 200 feet above the sea. Half a mile from the shore line in most places the bay is encircled by mountains that rise very abruptly to various altitudes up to 3,500 feet. The mountains approach nearer the shore line on both sides of the entrance. The lowlands at the head of the bay extend northeastward for several miles.

The terraced lowlands and the mountain slopes are heavily timbered up to an altitude of 2,500 feet. The ground in the timbered areas is generally covered with moss and underbrush and above timber line with a heavy matted growth of shrubs and grasses, so that natural bedrock exposures are exceedingly rare away from the coast. Geologic study is therefore greatly assisted by the numerous open cuts, strippings, and tunnels that have been made on the mining properties during the 30 years that have elapsed since gold was first discovered here in 1887. The timber is largely of excellent quality spruce and cedar and far exceeds in amount any probable future requirements for mining purposes.

The region has an abundant rainfall, so that the run-off is copious and fairly constant. The low elevation of the streams that gather on the terraced lowlands permits only a small amount of water power to be developed from them. There is, however, in the mountains south of the bay, a high hanging valley whose stream is said to be well adapted to large power development.

GENERAL GEOLOGY.

The rocks of the Funter Bay district include a highly altered bedded series, dominantly greenstone schist and subordinately limestone or marble, and a few small dikes of diabase, andesite, and diorite, which cut the bedded rocks at wide intervals. The schistose cleavage of the metamorphic rocks is generally parallel with the bedding planes. Locally intense crumpling and close folding on a small scale are apparent, but in general the bedded rocks lie in broad and gentle folds. Over considerable areas both schistosity and bedding are near the horizontal. Joint systems on both large and small scales cut the bedded rocks at high angles with the schistosity and bedding or near the vertical. The major joint planes in places persist for hundreds and even for a thousand feet or more with great regularity in strike and dip. Such large fractures were probably accompanied by some differential movement between the blocks which they separate, but there is no definite indication of the maximum displacement. These planes are generally marked by quartz veins, which range in thickness, in the different individuals observed, from mere films to nearly 60 feet. At one locality four approximately parallel veins were measured in a section 330 feet across, whose thickness aggregated 90 feet. Obviously the introduction of this amount of quartz in a narrow section involved displacement of masses of the rock. T-shaped and L-shaped bends in some of the veins indicate differential movements amounting at least to the thickness of the veins. Other veins, which gradually thin out to their ends, do not have this significance. Faults later than the veins and offsetting them occur only here and there, according to present evidence.

The metamorphism of the bedded rocks is for the most part of regional character and of earlier age than the igneous dikes or the quartz veins which are unsheared. Later metamorphic agencies have affected the bedded rocks locally, adjacent to the quartz veins, resulting in silicification and bleaching of the greenstone schists, accompanied by the introduction of sulphide minerals and in places of gold. Such minerals also occur in bands of greenstone schist without associated quartz veins at two localities, but they are not believed to represent a distinct period of mineralization.

ECONOMIC GEOLOGY.

The quartz veins and mineralized schists of the Funter Bay district are generally more or less auriferous, and since the time of the original discovery in 1887 several tracts have been held for mining purposes. The history of location, abandonment, and relocation of claims in the district is too tedious to narrate. The salient facts are that a great deal of prospecting and a little mining has been done, and at present four groups of claims are held, on only one of which development has advanced beyond the prospecting stage. These properties are the Portage group, the Seattle group, the Admiralty Alaska Gold Mining Co.'s holdings, and the Otterson claims.

PORTAGE GROUP.

The Portage group of claims are about 2 miles northeast of the head of Funter Bay, in a low, rolling timbered area. These claims are said to have been located about 1894, but little development work had been done prior to 1904, when Wright[1] visited the district. He describes the mineral deposits of the claims as follows:

> At the lower workings is an irregular vein apparently composed of a succession of lenticular quartz masses inclosed in slate. The strike of the lead corresponds with the northwest strike of the slaty structure, the dips being nearly vertical. The vein carries considerable pyrite and chalcopyrite with small amounts of galena, but assays are said to show that the ore is of low grade. A small shaft and open cuts expose the quartz at several points. Up the hill above these workings prospecting has been done on a belt of mineralized schist. This is exposed across a width of 30 feet and has a N. 10° W. strike and dip NE. 65°, the footwall being defined by an unmineralized and massive greenstone, the hanging wall by a gradual decrease in mineralization.

Additional prospecting has been done on the property year by year up to the present time, measured by the amount of assessment work required to hold title.

SEATTLE GROUP.

A number of claims, known as the Seattle group, about 2 miles southeast of the Portage group, have been held for the last five or six years, and it is reported that considerable work has been done in prospecting them. The geology is similar to that of the Portage group, the prospects being mainly in mineralized schists. These rocks are apparently similar to the mineralized schists near Youngs Bay, about 15 miles southeast of Funter Bay, and also to schists on Douglas Island, on the Yakima and Alaska Treasure properties.

ADMIRALTY ALASKA GOLD MINING CO.

LOCATION OF PROPERTY.

The holdings of the Admiralty Alaska Gold Mining Co. comprise two groups of claims, including the earliest locations made in the district. The lower group is on the south shore of the bay halfway to its head and includes the Tellurium, Uncle Sam, King Bee, Lone Star, and other less important claims. The upper group is on the north slope of the mountains half a mile to a mile southeast of the shore claims. It includes the Patterson, Heckler, Washington, Mountain Queen, and other claims. (See Pl. VI.)

HISTORY OF DEVELOPMENT.

The earlier history of this property is given by Wright[2] as follows:

> The first discoveries at Funter Bay were the Tellurium group, made in 1887 by R. Willoughby and C. Wier, of Juneau, but development in excess of the minimum

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[1] Wright, C. W., A reconnaissance of Admiralty Island: U. S. Geol. Survey Bull. 287, p. 150, 1906.

[2] Idem, p. 149.

legal requirements was not begun until 1894. In that year a Huntington revolving mill and a Frue vanner were installed at the Tellurium mine in order to thoroughly sample the ore, and favorable returns were reported from this experiment. In the following year the Alaska Willoughby Mining Co. bonded the property and installed a 10-stamp mill with four Frue vanners. They continued operations in 1895-96 and later sold their properties to the Funter Bay Mining Co., which continued developments on many claims.

The Funter Bay Mining Co. held the property until 1904, when it was acquired through the courts by J. W. Hunter, who had done the assessment work, to satisfy his claims for wages. The property was bonded early in 1915 by W. S. Pekovich, who later incorporated the Admiralty Alaska Gold Mining Co., to which he assigned his interests.

The mill installed by the Alaska Willoughby Mining Co. was used in 1895–96, when considerable ore from the Tellurium and Uncle Sam lodes was run. It was shut down before the Funter Bay Mining Co. acquired possession and remained idle until June, 1915, when Mr. Pekovich began operations. After a run of about eight months testing ores from the beach claims it was again shut down pending financial arrangements for enlarged operations. Except in these two short periods of productive operation little development in excess of the minimum legal requirements has been done on the property. The assessment work has consisted mainly in erratic prospecting, so that the properties are, on the whole, very poorly developed, considering that 30 years has passed since the original discovery was made.

The Tellurium, Uncle Sam, and King Bee lodes have supported practically all the productive mining and are therefore the best developed. The Tellurium lode is developed by a drift 123 feet long, driven from the beach just above tide level. For most of this distance it has been stoped out to the surface through a backing of 25 to 30 feet and with an average width of 5 feet.

The Uncle Sam lode is developed by a crosscut 98 feet long, leading from the mill to the vein, 228 feet of drifts, and about 1,000 feet of open-cut work. The vein is stoped out above the drift for 108 feet. A crosscut has been driven 70 feet on a fault plane about 200 feet from the mill crosscut, in the attempt to locate the offset portion of the vein underground. In the main drift 200 feet from the mill is a 30-foot winze sunk on a shoot of sulphide ore.

The King Bee lode is developed by an adit 200 feet long, open surface cuts 20 to 25 feet deep at short intervals for a distance of 1,000 feet, a shaft 110 feet deep, and crosscuts at the bottom of the shaft 30 feet toward the Uncle Sam vein and 132 feet toward the Tellurium vein. The shaft collar is on the beach below high-tide level. The cribbing employed to keep out the sea water has been destroyed, and it is now flooded. The vein has been stoped out to the surface above the adit for most of its length.

The other claims of the lower group are developed only by a few shallow surface pits.

The claims of the upper group have been prospected mainly by surface pits and strippings, but a little underground work has been done on some of them. There is an 85-foot shaft on the Patterson lode, a 51-foot tunnel on the Washington lode, a 40-foot tunnel on the Devil Club lode, and three tunnels aggregating about 650 feet on neighboring claims whose names could not be learned. About 50 exposures in all, a few of which were natural exposures, the others open cuts or strippings, were examined by the writer on the upper group of claims. Although some of the work done on these claims may have been overlooked, it is believed that the list given represents very closely the extent of development thus far accomplished.

Improvements on the property include the mill, bunk houses, shops, tramways, ditch lines, etc. The mill has its original equipment, consisting of ten 850-pound stamps, four Frue vanners, a 3½-inch Huntington revolving mill, a 9 by 14 inch Blake crusher, suitable boilers, engines, compressor, water wheels, ore elevator, etc. Quarters are available for about 30 men. The shops include a well-equipped assay laboratory.

Water is delivered to a penstock back of the mill by two ditches, one 5,000 feet long from the southwest and one 6,000 feet long from the northeast. A head of about 60 feet is developed.

THE LODES.

GENERAL FEATURES.

The lodes that occur on the property of the Admiralty Alaska Gold Mining Co. are all quartz veins. The cleavage and apparent bedding of the schistose country rock are near the horizontal over most of the area, and the veins occupy fissures that cut across these structural features at high angles. Many of the veins show great persistence in thickness and trend, and there is nowhere any suggestion of the bluntly lenticular form shown in the veins of the Portage group. Mineralization in the schists not directly associated with quartz veins is also lacking. It would appear that these differences are related to the structure of the bedrock encountered by the mineralizing solutions. In the Portage area the dips are high and the slaty and schistose structure afforded numerous channels for the upward passage of solutions, resulting in disseminated mineralization. In the Admiralty Alaska area, on the other hand, the only available channels were the stronger fissures cutting across the other features of the rock structure, along which the movement of solutions was definitely concentrated.

The introduction of the quartz veins was accompanied by local alteration of the adjacent schists. This action included silicification and the development of sericite and sulphide minerals. Some of the altered schists adjacent to the quartz veins are said to give substantial assays for gold.

The veins generally have a composite structure, as if they had gained their thickness by the addition of successive layers. The layers differ in color and mineral content in the same section and are generally separated in weathered exposures by a micaceous iron-stained gouge. Layers relatively rich in sulphide minerals and metallic gold may occur in the same vein with layers that are almost barren.

Pyrrhotite, pyrite, and galena are the most abundant sulphide minerals. Sphalerite occurs sparingly in places. Iron carbonate is abundant in some veins, especially in those that give the higher assays for gold. In these respects the mineralization in the Funter Bay district resembles that of lodes on the mainland near Juneau.

LODES OF LOWER GROUP.

There are three principal lodes on the lower group of claims whose characteristics have been revealed by development work. These are he Uncle Sam, King Bee, and Tellurium lodes, named in geographic order from southeast to northwest. The distance between the Uncle Sam and King Bee near the shore line is 100 feet, and between the King Bee and Tellurium about 700 feet. Near the beach the Uncle Sam vein strikes N. 55° E., the King Bee N. 60° E., and the Tellurium N. 65° E., so that their trends converge slightly to the northeast. A short distance from the beach the Uncle Sam vein turns to N. 65° E., and two parallel veins, not seen at the beach, appear southeast of the Uncle Sam at intervals of 10 and 20 feet.

The Uncle Sam vein has a width in the mined section of 6 to 10 feet. Farther northeast, where exposed in open cuts, it is only 1 to 3 feet wide. The parallel veins noted above are 6 and 10 feet wide. The quartz of the Uncle Sam vein is of the milky variety, but it generally has a reddish aspect due to iron staining. Sulphide minerals, chlorite, and iron carbonate occur irregularly through its mass, finely disseminated in some places and segregated into irregular patches in others. A shoot of sulphide ore occurred in the vein about 100 feet from the mill crosscut, standing nearly vertical, about 8 feet across at the drift level and pinching downward for 30 feet. A shipment of 22 tons of ore taken from the shoot and sent directly to the smelter is said to have yielded $134 a ton in gold. The gold occurs mainly with the sulphides throughout the vein, so that the tenor of the ore can be estimated from its appearance.

The King Bee vein is similar to the Uncle Sam in appearance and size but appears to hold its width more uniformly back from the beach. It is said to persist in size and gold tenor to the bottom of the 110-foot shaft. This lode supplied a large part of the ore milled by the Alaska Willoughby Mining Co. and is probably the most promising of all the lower lodes for future development.

The Tellurium lode is said to be 10 feet wide in the beach cropping, which is now covered by shingle. It pinches gradually back from the beach and at the face of the 123-foot drift is only a few inches wide. Sulphide minerals, chiefly pyrrhotite, are abundant in the vein matter and along the walls. Calcite and iron carbonate also occur as gangue minerals. The ore mined from this ledge is said to have had the highest average value found in all the workings.

The other veins exposed on these claims have been but little developed, a fact which may indicate that they are relatively lean. A white quartz vein about 6 feet wide near the Tellurium examined by the writer showed no sulphide minerals except a little sphalerite and on assay gave not even a trace of gold. The veins southeast of the Uncle Sam contain no visible sulphides in the surface croppings.

As the property now stands there is little ore in sight above tide level in the lodes of the lower group of claims. The backing of most of the drifts has been mined out, so that future development must look to the extension of the veins below tide level. Any project for their development must include plans for pumping not only the surface waters, which now enter through the long open cuts, but also more or less sea water that will seep in along the veins. Surface waters are known to sink along the veins in places and probably reach the sea through underground crevices. This flow would undoubtedly be reversed if lower levels were opened in the mines.

The extent and availability of the lodes below sea level will be known only after much systematic prospecting has been done. It would appear that diamond drilling could be used advantageously in testing veins adjacent to the one that may be chosen for the first development work at depth.

LODES OF UPPER GROUP.

A large number of distinct veins were examined by the writer in the area of the upper group of claims, which lie on the steep northerly mountain slope half a mile to a mile southeast of the lower group. It is likely that not all existing exposures were found and also that there are many veins that have no visible croppings. Enough was seen, however, to show that veins on these claims are more numerous and much larger than those nearer the coast.

In working without an adequate base map it was impossible to show the positions of the veins examined or to learn the names of the claims on which many of them were located.

The most development work has been done on the Patterson and Heckler claims. The Patterson claims are about a mile southeast of the mill; the Heckler claims lie east of them.

Veins are developed on the Patterson claims at two places; at one by an 80-foot shaft and at the other by an open cut. The shaft is sunk on a 6-foot vein containing sulphides and bordered by bleached schists that are strongly mineralized. The open cut crosses four veins aggregating 6 feet of quartz in a width of 16 feet. The main veins consist of milky quartz, but in places bodies of bluish translucent quartz containing albite crystals as much as half an inch in length project from them out into the schists along the structure planes. Both types of quartz are said to be gold bearing.

On the Heckler claims, at an elevation of 1,700 feet, a stripping shows a quartz vein 57 feet across. The section northeast of this cropping along the hillside includes three other veins, two of them 10 feet and the other 12 feet wide, giving an aggregate of 89 feet of quartz within a space of 330 feet. The 57-foot vein is said to be ore; the other veins are not known to have been sampled. But little mineralization is apparent in any of these veins.

At an elevation of 1,360 feet on the Heckler property, directly down the slope from the exposures just described, is the outcropping of the so-called Heckler blanket vein. The vein strikes N. 45° E. and dips 60° NW., conforming with the slope of the hill. It is 3½ to 5 feet thick and has an overburden of bleached mineralized schist 6 feet thick. The vein has been stripped for 90 feet down the slope, over a width of 30 feet. It shows a very pronounced laminated structure. Some laminae are very rich in sulphide minerals and iron carbonate. A layer a few inches thick near the hanging wall contains visible gold and the whole vein is said to give especially high assays for gold. Weathering of the sulphides and iron carbonate has produced large quantities of iron oxide, which fills crevices between the more distinct laminae and also numerous vugs that are lined with quartz crystals.

Southwest of the "blanket vein," at an elevation of 900 feet, a 200-foot tunnel has been driven on a 6-inch vein. The tunnel is said to have been planned to undercut some of the larger veins of the property about 700 feet from the portal. The 6-inch vein is made up of several laminae with margins of interlocking quartz crystals. It is rich in pyrrhotite, pyrite, and iron carbonate, and where weathered all crevices and vugs are filled with iron oxide. It is said to have a high gold tenor. The vein persists with even thickness and structure for the whole length of the tunnel and is exposed at intervals on the slope above the tunnel for several hundred feet. In some of the higher exposures it contains arsenopyrite and pyrrhotite.

Many other veins, 2 to 10 feet thick and trending in various directions, were examined in natural outcrops, open cuts, strippings, and short tunnels in the course of the traverse over the upper group of claims. Their abundance and complex structure indicate that the bedrock over an area of a square mile or more is intricately seamed with intersecting quartz veins of minable size. Evidence of more or less mineralization is generally apparent, though there are croppings here and there without visible sulphide minerals.

The first requirement for further development of the property is an accurate base map, on which the veins may be plotted. Then systematic prospecting and assay work should be employed to determine the extent and relations of valuable lodes and also the best scheme of exploitation.

OTTERSON CLAIMS.

The Otterson claims are southwest of the upper group of the Admiralty Alaska property, in a corresponding topographic position. They were not seen by the writer, but it was learned that the general aspect of the lodes is similar to those of the property to the northeast. They are said to be well-defined quartz veins 20 feet or less in width, in which gold is associated with sulphide minerals. Specimens from some of them show visible gold embedded in quartz and in pyrrhotite patches in the quartz. Prospecting work was in progress on the property in the summer of 1916.

GOLD PLACER MINING IN THE PORCUPINE DISTRICT.

By HENRY M. EAKIN.

INTRODUCTION.

The Porcupine gold-placer district includes an area drained by westerly headwater tributaries of Chilkat River that centers about 40 miles northwest of Haines, a small town on the shore of Lynn Canal, 75 miles north of Juneau. Placer gold is known to occur in the basins of four tributaries of the Chilkat, which, named in order from north to south, are Bear Creek and Klehini, Salmon, and Takhin rivers. The original discovery in 1898 was made on tributaries of Klehini River which have since been the chief source of production. The other basins have witnessed more or less prospecting and desultory development work, but they have contributed little to the output of the district. For several years mining operations in the district have been confined to Porcupine and Glacier creeks, which are southerly tributaries of Klehini River, 12 and 14 miles respectively from its mouth.

The region was first visited by a Geological Survey party in 1899, when an exploratory expedition passed through it on the way from Pyramid Harbor to Eagle.[1]

In 1903 C. W. Wright, of the Survey, spent three weeks in further examination of the district, and the results of his studies were published the following year.[2] The writer visited the district early in the summer of 1916, spending two weeks in the examination of properties now under development and in the study of bedrock and glacial geology related to the formation of the placer deposits. The publications of the earlier investigations have been freely consulted in assembling the matter of this paper.

TOPOGRAPHY.

The region lies within the coastal mountain province of southeastern Alaska and partakes of its general characteristics of strong relief and glacially developed forms. Summit elevations along the principal divides generally range between 3,000 and 5,000 feet, but individual peaks rise 6,000 to 7,500 feet above sea level. The main valleys are broad and steep sided and are floored by heavy gravel deposits of glacial streams. The topography has a smoothed aspect up to an altitude of about 3,000 feet, marking the level reached by ice during earlier periods of glaciation. Glaciers of considerable size still persist on the headwaters of the streams that drain the higher divides.

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[1] Brooks, A. H., A reconnaissance from Pyramid Harbor to Eagle City, Alaska: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 374-376, 1900.

[2] Wright, C. W., The Porcupine placer district, Alaska: U. S. Geol. Survey Bull. 236, 1904.

EROSIONAL HISTORY.

During the period of more extensive glaciation of the region both trunk and tributary valleys were deeply scoured by ice action, but the main valleys were generally lowered below the levels of their tributaries, which thus became hanging valleys. When the ice had retreated the streams from the hanging valleys found abrupt declivities in their courses at the margins of the main valleys. These conditions favored the erosion of canyons in tributary valleys and the deposition of detritus in the form of alluvial fans along the margins of the main valleys. These features are well illustrated in the present canyons and alluvial fans of Glacier and Porcupine creeks.

In places in the Porcupine Valley at the side of the present canyon there are so-called bench deposits. These consist of stream gravels overlain by glacial detritus. It is evident that these deposits occupy sections of a canyon, older than the present one but due to similar processes, which was in some places followed and in others missed by the course of Porcupine Creek when the last intrenchment began. Two distinct ice advances are thus indicated, each of which was followed by intrenchment of the hanging-valley streams.

The modern canyon has been eroded to a lower level than the earlier one throughout the middle and upper sections of Porcupine Valley. Near the lower end of the valley the conditions are not so simple, and it seems likely that the stream accomplished considerable intrenchment along more than two courses.

The identity and relations of the different bedrock canyons at this place could not be fully deciphered from the available exposures. It is clear, however, that the Porcupine was controlled by a lower base-level than that afforded by the present position of Klehini River at the time of maximum intrenchment in each position.

In Glacier Creek valley also there is evidence of two distinct ice advances, with an intervening period of stream erosion. An extremely deep and narrow bedrock gorge filled with glacial detritus has been traced for some distance along the lower part of the valley beneath the modern stream gravels. A base-level of erosion much lower than the present is indicated, the same as in the lower Porcupine Valley. The upstream extension of this older canyon is not now evi-

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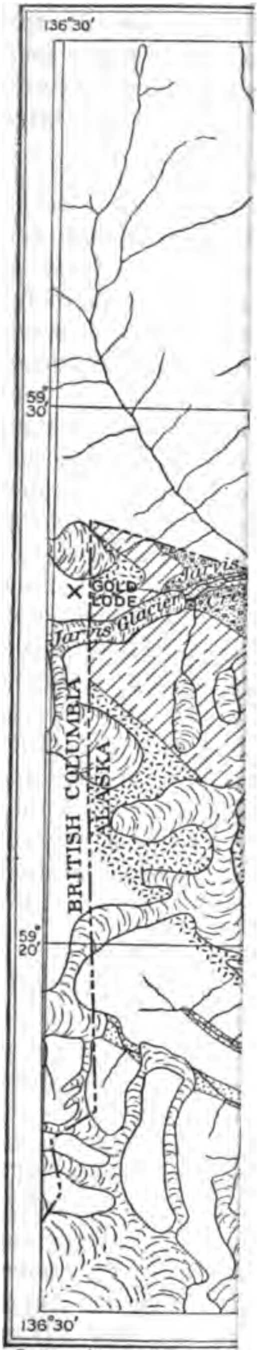

Drainage from maps prepared by International Boundary Commission

MAP

dent. It may have been destroyed by later ice erosion in Glacier Creek valley or it may have been followed by the stream in its last intrenchment. The narrowness of the valley favors the latter interpretation.

PLACERS.

The concentration of placer gold took place in conjunction with the intrenchment of the hanging-valley streams wherever their courses traversed zones of mineralized bedrock. The placers are therefore of two distinct ages, corresponding with the separate periods of stream erosion. The concentrations are generally found in a thin stratum of stream gravels lying on the bedrock bottoms of the canyons. Locally, as below the falls on McKinley Creek, gold has been found on bare bedrock practically without associated gravels. The gold-bearing stratum is generally overlain by barren or very low grade gravels that are progressively deeper downstream. The stream gravels in the bottoms of the older canyons, which are gold bearing in places, are overlain by glacial detritus whose depth is generally measured by the height of the canyon walls. In the lower section of Glacier Creek modern gravels overlie the glacial fill of the older canyon, which extends to a great depth below the present stream and has a much steeper grade. At the lower ends of the modern canyons, where the alluvial fans begin, there are certain concentrated deposits that extend into the gravels somewhat above bedrock. They are less regular in form and of lower grade than the gravels within the confines of the canyons and extend but a short distance out into the Klehini Valley. Apparently the alluvial fans are devoid of notably concentrated placer deposits except possibly at their very heads.

GEOLOGY.

The solid rocks of the district consist mainly of metamorphosed sedimentary types, including limestones, slates, phyllites, and schists. The schists are apparently developed only locally through excessive alteration of beds that are generally represented by slates and phyllites. Likewise silicification of limestone has produced quartzitic beds in small areas.

The general area of sedimentary rocks is bordered on the northeast by the great belt of diorite that extends southeastward in the Coast Range. Outlying masses of diorite are intruded into the sedimentary rocks for some distance southwest of the principal contact. The general distribution of these rocks is indicated on the geologic map (Pl. VIII), which is reproduced, with slight corrections, from a map drawn by Wright.[1]

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[1] Wright, C. W., The Porcupine placer district, Alaska: U. S. Geol. Survey Bull. 236, pl. 5, 1904.

The structure of the sedimentary rocks has not been worked out in detail, but the observations that have been made indicate that it is exceedingly complex. The beds are steeply tilted wherever observed, dips of 75 to 90° being common. The apparent trend of the great limestone band that crosses the lower courses of Glacier and Porcupine creeks is northwesterly. The limestones of the Klehini Valley above Jarvis Creek also strike northwest, and this is the direction of the larger igneous bodies of the region. However, in many places in Klehini and Jarvis valleys where observations on the structure of the slates were made the strike is northeast. The apparent differences in the structure of the slates and limestones suggests that the limestones may be younger and overlie the slates unconformably. This interpretation gains added weight from the fact that the slates have a structure indicating strong compression, whereas the limestones are massive and unsheared.

The general age of the bedded rocks is indicated by fossils found in the limestones on Porcupine Creek.

A small collection made by Wright[1] in 1903 was doubtfully identified as Lower Carboniferous by G. H. Girty, an identification which was corrected the following year, when larger collections were made at Pybus and Herring Bays.[2] The first collection, which was obtained on Porcupine Creek, contains the following specimens, with revised identifications:

Crinoid fragments.
Productus aff. P. mammatus.
Productus aff. P. gruenewaldti.
Spirifer aff. S. marconi and S. musakheylensis.
Camarophoria aff. C. margaritovi.

The same fauna is more completely shown in collections from Saginaw Bay, Kuiu Island, and the facies appears to be that of the *Spirifer arcticus* zone, which, it is believed, may be correlated with the Russian Artinskian.

The indications are that the clastic sedimentary rocks are older rather than younger than the limestones. Presumably the bedded rocks of the region all belong to the Paleozoic, and at least part of them are definitely of Carboniferous age.

MINERALIZATION.

The very general mineralized condition of the sedimentary rocks of the region is well described by Wright,[3] who says:

> The sedimentary rocks have all been more or less mineralized by stringers and veins of quartz and calcite, but an especially noteworthy impregnation of iron sulphides forms an interrupted zone of mineralization in the southern portion of the sedimentary

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[1] Wright, C. W., op. cit., p. 16.

[2] Idem, A reconnaissance of Admiralty Island: U. S. Geological Survey Bull. 278, p. 143, 1906.

[3] Idem, The Porcupine placer district, Alaska: U. S. Geol. Survey, Bull. 236, pp. 17-18. 1904.

series. The sulphides in the slates occur as films or frequently as lenticular masses a few inches in width, parallel with the bedding. Two samples of the mineralized slates, one an average across several feet and the other from a rich seam, gave, respectively, $0.41 and $2.48 per ton in gold. Samples from near the mouth of the Porcupine, where the slates are apparently unmineralized, taken by Mr. Brooks during his short visit to this region in 1899, gave traces of both gold and silver.

The quartz veins are not very abundant and as a rule are short and small, often merely stringers parallel with the structure of the slates. A few which cut directly across the formation carry galena and sphalerite, with a small amount of chalcopyrite, and though quite narrow, often persist for considerable distances. Calcite veins, which are more numerous than those of quartz, are usually a foot or more in width, and are often weathered to a light-brown color on the surface, while of a bluish color and fine granular structure when freshly broken. They often carry cubes of pyrite, which occasionally measure an inch across. From veins of this nature up McKinley Creek some native gold has been reported.

Besides the small veins a quartz ledge 100 feet wide outcrops at an elevation of 2,000 feet on the ridge south of Porcupine. Although apparently quite barren, a small sample from this gave an assay value of $5.28 in gold. A similar ledge occurs across the Klehini at 1,500 feet elevation, on the ridge west of Boulder Creek. About 2 miles below Porcupine is a third mineralized deposit rich in sulphides, with calcite as gangue mineral, but a sample taken here gave an assay value of only 41 cents.

The general zone of mineralization from which the placers of Klehini and Salmon River basins have been derived appears to be elongated in a northwesterly direction, extending from a locality south of Salmon River across the basins of Porcupine, Glacier, and Jarvis creeks and into the mountain mass north of Jarvis Glacier. The richness of mineralization varies from place to place, and there are large areas of lean or barren rock in this zone. But there are also remarkably large areas in which sulphide minerals are generally abundant and samples from which are reported to show a substantial gold content on assay. A band of this sort that cuts across Cahoon Creek near its mouth in a slate formation shows abundant quartz veining and sulphides for a width of nearly 1,200 feet. Random samples taken across this belt are reported to assay as much as several dollars a ton, and a large number of assays ranged between $1 and $2 a ton.

The northwesternmost point along the general zone of mineralization at which gold has been found is in the mountains north of the lower end of Jarvis Glacier. Here, at an elevation of about 4,500 feet, are several gold quartz ledges in a granitic country rock some 300 feet above its contact with limestone. The lower and apparently the most valuable of the ledges is traceable for over 2,000 feet along the strike. It ranges from 1 foot to 4 feet in width. Assays of numerous samples are reported to give from a few dollars to $70 a ton, the higher tenor generally occurring where the vein is relatively narrow. A silver content of a few ounces a ton is indicated in most samples. Picked specimens give much higher assay returns.

Southeast of the main placer area on the slope north of Salmon River are a number of narrow silver-lead veins that show still another type of mineralization in the district. So far as known the largest are less than a foot in width. The maximum gold tenor of samples from these veins is said to be about $3 a ton, silver 60 ounces a ton, and lead about 35 per cent. One sample shows a copper content of nearly 3 per cent.

The mineralization that has furnished the placer gold of Bear Creek has not been studied geologically. Prospectors report that a broad zone along the ridge west of Bear Creek is heavily pyritized and that it contains, locally at least, commercial grades of copper ore. Specimens from this locality show iron, copper, and zinc sulphides in vein form.

HISTORY OF DEVELOPMENT.

Gold was first discovered in the Porcupine district in 1898. The next year mining operations were begun on Porcupine Creek, and the great number of prospectors who assembled staked claims on several other creeks of the district. Gold-bearing gravels were found on Bear Creek, on several tributaries of Salmon River, and on the head of Takhin River, but up to the present time productive operations have been almost entirely limited to Porcupine Creek and its tributaries. A little mining was done on Nugget Creek from 1902 to 1911. The ground was then abandoned and no further work has been done. It is estimated by local operators that about $6,000 worth of gold was produced. The gold production of Porcupine Creek and its tributaries from 1898 to 1903 is given by Wright [1] as follows:

Gold production of the Porcupine region, 1898–1903.

1898	$1,000	1902	$140,000
1899	9,000	1903	150,000
1900	50,000		
1901	110,000		460,000

The production from these creeks is said to have continued at the rate of $150,000 a year until 1906, when the principal works were destroyed by an unusual flood. From 1907 to 1909 large operations were discontinued, and the only production was made by a few laymen who worked small lots of ground by hand. Production on a large scale was resumed in 1910, and it is reported that an average yearly output of $50,000 was maintained until 1915, when another disastrous flood occurred. The total output of the district from 1898 to 1916, inclusive, estimated on the basis of these very incomplete data, is about $1,200,000.

In 1908 the Porcupine Mining Co. was organized to exploit the placers of the main Porcupine Creek on a large scale. It was financed in the Eastern States, and in view of the equipment installed in the next few years it must have had a large investment fund. The first move of the new company was to construct a flume a mile long, 24 to

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[1] Wright, C. W., op. cit., p. 13.

30 feet wide, and 6 feet deep, supported on piles, to carry the waters of Porcupine Creek past the placer ground to be worked. This piece of construction, which required nearly a million feet of lumber and several thousand piles, was completed late in the summer of 1909, and mining was begun at the lower end of the canyon. This company operated until August, 1915, when the lower part of the flume was demolished and the pits were filled in by a flood. In the last few years operations were conducted under receivership but with the same local management.

After the disastrous flood of 1915 the property and holdings of the company were taken over by the Alaska Corporation. This concern in 1916 repaired the upper section of the old flume, constructed a new high-line flume to deliver water to the giants, and began the reexcavation of the buried workings.

Little mining was done on the tributaries of Porcupine Creek before 1908, when the Cahoon Creek Gold Mining Co. began work on McKinley and Cahoon creeks. This company has continued to operate to the present time, working out the placers on Cahoon Creek near its mouth and for about 2,000 feet down McKinley Creek below Cahoon. The plan followed in the operations on McKinley Creek was essentially similar to that employed on Porcupine Creek. The stream was diverted into a wooden flume, making the stream bed available for hydraulic mining. Below the workings on McKinley Creek the stream runs through a narrow box canyon. The difficulty of diverting the stream in this reach has thus far prevented the exploitation of the gravels of its bed. In 1916 the company was engaged in working the placers of a high, glacially filled channel on the right side of McKinley Creek, opposite the reach of the modern channel that has been worked out.

A little mining was done on the head of Cahoon Creek in the early days of the camp, but these operations are said to have met with slight success, and the hope of working this ground on any large scale has long been abandoned. However, a little prospecting and "sniping" have been done from time to time by laymen.

The most notable developments in the district in the last few years have been the investigation of the Glacier Creek placers by drilling and the installation of a large hydraulic plant to work this ground. The Glacier Creek placers were staked in the early days of the district, but repeated attempts to prospect and mine the ground by ordinary methods failed owing to the depth of the gravels and the abundance of ground water. In 1911 the claims, which had been abandoned by the previous holders, were restaked, and systematic drilling was begun. Drill sections across the valley bottom were made at short intervals for over a mile upstream from the margin of the Klehini Valley. On the basis of the results of this investigation extensive preparations were made to work a lower section of the valley 4,200 feet long by hydraulic methods. The installation of a very complete plant, including dams, flumes, pipe lines, giants, and hydraulic elevator, was finished in midsummer, 1915, but operation was prevented for the rest of the season by unusual floods.

In 1916 work was started early in spring, but owing to damage done to the workings by a flood the later part of June the season netted but little productive operation.

SUMMARY OF MINING IN 1916.

Mining in the Porcupine district in 1916 was confined to Porcupine Creek, its main east tributary, McKinley Creek, and Glacier Creek. A single hydraulic plant worked on each stream throughout the summer. The principal work done on Porcupine and Glacier creeks consisted of the installation of hydraulic equipment and the repairing of damage done to workings and equipment by floods, so that little productive mining was accomplished. Two small plants were worked by hand on the lower Porcupine part of the summer. The plant on McKinley Creek opened a new pit in an old elevated channel and worked out a considerable area, although the operations were hampered somewhat by the presence of an overburden of glacial till 60 feet thick in which there are numerous large boulders.

About 50 men at an average were employed during the summer in the whole district, being divided about equally among the three active creeks. Although the production for 1916 was small, it is reported that the plants have all been put in good repair and that conditions indicate that a very considerable production may be made in 1917.

WATER-POWER INVESTIGATIONS IN SOUTHEASTERN ALASKA.[1]

By George H. Canfield.

INTRODUCTION.

The streams of Alaska have been important factors in its industrial growth. The success of placer mining in northern and central Alaska has depended primarily on the water available for hydraulicking and dredging, and in southeastern Alaska water power has long been used by mines, canneries, sawmills, and other industries, although until recently most of the plants have been small.

Since 1906 the United States Geological Survey has made systematic studies of the water resources of Alaska. Investigations with special reference to placer mining have been made in Seward Peninsula[2] and the Yukon-Tanana region,[3] and reconnaissance surveys for water power have been made about Prince William Sound, Copper River, Kenai Peninsula, and in other parts of southeastern Alaska.

In the summer of 1914 Leonard Lundgren, district engineer of the Forest Service, made a reconnaissance of water-power sites to determine the possibility of establishing the pulp industry in the Tongass National Forest, which covers a large part of southeastern Alaska. In connection with this reconnaissance a census of water powers was taken (see following table), which has been revised by Mr. Lundgren to January 1, 1917, and is here published by courtesy of the Forester.

Developed water powers in southeastern Alaska Jan. 1, 1917, in horsepower.

[Prepared by Leonard Lundgren, district engineer, U. S. Forest Service.]

Ketchikan region:		
Citizens Light, Power & Water Co.	2,000	
New England Fish Co.	2,200	
Miscellaneous plants	1,000	
		5,200
Wrangell region		0

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[1] In cooperation with the United States Forest Service.

[2] Henshaw, F. F., and Parker, G. L., Surface water supply of Seward Peninsula, with a sketch of the geography and geology by P. S. Smith, and a description of methods of placer mining by A. H. Brooks: U. S. Geol. Survey Water-Supply Paper 314, 1913.

[3] Ellsworth, C. E., and Davenport, R. W., Surface water supply of the Yukon-Tanana region, Alaska: U. S. Geol. Survey Water-Supply Paper 342, 1915; A water-power reconnaissance in south-central Alaska, with a section on southeastern Alaska by J. C. Hoyt: U. S. Geol. Survey Water-Supply Paper 372, 1915.

Sitka region:			
Sitka Wharf & Power Co		350	
Chichagoff Mining Co		750	
Miscellaneous plants		150	
			1,250
Juneau region:			
Alaska-Treadwell Mining Co.:			
Douglas Island plant	4,000		
Sheep Creek plant	4,100		
Nugget Creek plant	5,700		
		13,800	
Alaska-Gastineau Mining Co.:			
Salmon Creek plant, No. 1	5,000		
Salmon Creek plant, No. 2	5,000		
Annex Creek plant	5,000		
		15,000	
Alaska Electric Light & Power Co		1,000	
Miscellaneous plants		1,000	
			30,800
Skagway region			100
			37,350

During the last few years some large water-power plants have been installed near Juneau to supply power for mining, and attention has been called to the feasibility of improving other power sites in that region and elsewhere in southeastern Alaska, to meet the increasing demand for power to be used in mining, lumbering, and fisheries, and the possible future demand for its use in the manufacture of wood pulp and electrochemical products. The streams on which it is possible to develop power and the bays or other water bodies into which these streams discharge are listed in the following table and shown on the map (Pl. IX):

Streams affording power sites in southeastern Alaska, with position or water bodies into which they flow.

Mainland.

Porcupine River, near Porcupine.[1]
Endicott River, west coast of Lynn Canal.
Sherman Creek.
Cowie and Davies creeks, Berners Bay.
Lemon Creek, near Juneau.[2]
Gold Creek, at Juneau.
Sheep Creek, near Juneau.
Carlson Creek, Taku Inlet.[3]
Turner Lake outlet, Taku Inlet.[4]
Speel River, Speel River project, Port Snettisham.[5]
Grindstone Creek, north shore of Stephens Passage.[5]
Rhine Creek, north shore of Stephens Passage.[5]

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[1] Gaging station maintained in 1909 by Porcupine Gold Mining Co.

[2] Gaging station maintained for short period by mining company of Juneau.

[3] Gaging station being maintained by Alaska-Gastineau Mining Co. of Juneau.

[4] Gaging station maintained in 1908 and 1909 by Alaska-Treadwell Gold Mining Co.

[5] See list of miscellaneous measurements at end of report.

Long Lake outlet, Speel River project, Port Snettisham.[1]
Crater Lake outlet, Speel River project, Port Snettisham.[1] [2]
Tease Lake outlet, Speel River project, Port Snettisham.
Sweetheart Falls Creek, south arm of Port Snettisham.[3]
Port Houghton, Stephens Passage.
Farragut Bay, Frederick Sound.
Mill Creek, near Wrangell.[3]
Bradfield Canal, upper end of Cleveland Peninsula.
Smugglers Cove, southeast shore of Cleveland Peninsula.
Helm Bay, southeast shore of Cleveland Peninsula.
Shelockum Lake outlet, Bailey Bay.[3]
Chickamin River, east shore of Behm Canal.
Rudyerd Bay, east shore of Behm Canal.

Baranof Island.

Port Conclusion, southeast coast.
Patterson Bay, east coast.
Red Bluff Bay, east coast.
Cascade Bay, east coast.
Baranof Lake outlet, Warm Spring Bay, east coast.[3]
Kasnyku Bay, east coast.
Green Lake outlet, Silver Bay, west coast.[3]
Necker Bay, west coast.
Deep or Redoubt Lake, west coast.

Chichagof Island.

Slocum Arm, west coast.
Suloia Bay, Peril Strait.
Khaz Bay, west coast.
Freshwater Bay, east coast.
Sitkoh Bay, southeast coast.
Basket Bay, southeast coast.
Pinta Bay, west coast.

Admiralty Island.

Kootznahoo Inlet, west coast.
Hood Bay, west coast.

Kosciusko Island.

Davidson Inlet.

Prince of Wales Island.

Karta River, Karta Bay.[3]
Whale Passage, behind Thorne Island, northeast coast.
Myrtle Lake outlet, near Niblack post office.
Reynolds Creek, near Coppermount.[2]

Revillagigedo Island.

Orchard Lake outlet, at Shrimp Bay.[3]
Beaver Falls, George Inlet.
White River, George Inlet.
Swan Lake outlet, east shore near head of Carroll Inlet.
Fish Creek, Thorne Arm.[3]
Gokatchin Creek, Thorne Arm.[2]
Ketchikan Creek, at Ketchikan.[3]

Annette Island.

Tamgas Harbor.

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[1] Gaging station maintained since January, 1913, by the Speel River project of Juneau.
[2] See list of miscellaneous measurements at end of report.
[3] Gaging station maintained by Geological Survey.

Lack of definite information in regard to the quantity of water available and other physical factors that determine the feasibility of a power site has been one of the principal impediments to development. For this reason a systematic investigation, designed to determine the location and the feasibility of water-power sites in southeastern Alaska, was begun by the Geological Survey, in cooperation with the Forest Service, in the spring of 1915.

The practicability of a water-power site depends on the quantity of water available, the fall, and the possibility of storing water. Information in regard to fall and storage can be obtained by surveys at any time, but the volume and distribution of flow can be determined only by observations extending over several years, as future flow must be predicted from that of the past. In beginning the investigations, therefore, the collection of stream-flow data was given precedence and constituted the principal work. Some general information, however, has been obtained, and in the fall of 1915 a few rainfall stations were established at higher elevations to supplement observations at mean sea level by the United States Weather Bureau. As a result of the investigations records of flow are now available for 19 gaging stations, as shown by the following list, and indicated by corresponding numbers on Plate IX. The date of establishment is indicated in parentheses.

1. Fish Creek near Sea Level, Revillagigedo Island (May 19, 1915).
2. Ketchikan Creek at Ketchikan (established Nov. 1, 1909; discontinued June 30, 1912; reestablished July 1, 1915).
3. Swan Lake outlet at Carroll Inlet, Revillagigedo Island (Aug. 24, 1916).
4. Orchard Lake outlet at Shrimp Bay, Revillagigedo Island (May 28, 1915).
5. Shelockum Lake outlet at Bailey Bay (June 4, 1915).
6. Karta River at Karta Bay, Prince of Wales Island (July 16, 1915).
7. Mill Creek on mainland near Wrangell (June 17, 1915).
8. Green Lake outlet at Silver Bay, near Sitka (Aug. 22, 1915).
9. Baranof Lake outlet at Baranof, Baranof Island (June 28, 1915).
10. Sweetheart Falls Creek near Snettisham (July 31, 1915).
11. Crater Lake outlet at Speel River, Port Snettisham (Jan. 23, 1913).
12. Long Lake outlet at Port Snettisham (Jan. 23, 1913).
13. Long River below Second Lake at Port Snettisham (Nov. 11, 1915).
14. Speel River at Port Snettisham (July 15, 1916).
15. Grindstone Creek at Stephens Passage (May 6, 1916).
16. Carlson Creek at Sunny Cove, Taku Inlet (July 18, 1916).
17. Sheep Creek near Thane (July 26, 1916).
18. Gold Creek at Juneau (July 20, 1916).
19. Sherman Creek at Kensington mine, Lynn Canal (Aug. 17, 1914).

The available power sites in each area were carefully considered, and gaging stations were established at those which apparently afforded the greatest opportunities for development.

The records have been collected in accordance with the standard methods used elsewhere in the United States by the Geological Survey. Owing to the inaccessibility of the stations, water-stage recorders were used at all the stations except that on Ketchikan Creek, and cables have been installed from which discharge measurements are made. Special arrangements were made for observations through the winter to obtain a record of the low-water flow which occurs at that season.

The data collected at the gaging stations are presented in the following pages and include a general description of each station and tables showing the results of discharge measurements and the computed daily discharge.

Much of the work has been made possible by the use of the Forest Service launches, on which transportation has been furnished to the engineers and others engaged in installing and maintaining the stations. The local knowledge of the Forest Service employees has also been of great assistance in carrying on the work, and special acknowledgment is due to W. G. Weigle, forest supervisor at Ketchikan, who has represented the Forest Service in the cooperation; to Leonard Lundgren, district engineer; and to George L. Drake, J. W. Wyckoff, C. T. Gardner, George H. Peterson, James Allen, W. H. Babbitt, Lyle Blodgett, and Milo Caughrean, who have assisted in various ways.

During the winter of 1916–17 the field work was carried on by C. O. Brown, assistant engineer, United States Geological Survey.

The following individuals and organizations assisted in maintaining gaging stations as indicated:

T. J. Jones, Seattle, Wash., furnished a Stevens water-stage recorder, materials, and labor for installing a gage on Swan Lake outlet.

The Alaska Gastineau Mining Co. installed gages and furnished gage-height records for Gold Creek near Juneau, Sheep Creek near Thane, and Carlson Creek at Sunny Cove.

The Alaska Taku Mining Co. furnished a Lietz gage, labor, material, and transportation for the installation of a gage on Grindstone Creek at Stephens Passage.

The Speel River Project (Inc.), of Juneau, installed and maintained gages and furnished gage readings and discharge measurements for Crater Lake outlet at Speel River, Long Lake outlet at Port Snettisham, Long River below Second Lake, and Speel River at Port Snettisham.

The Kensington Mining Co., of Comet, furnished gage readings for Sherman Creek at Kensington mine.

The Citizens Light, Power & Water Co., of Ketchikan, furnished gage readings for Ketchikan Creek at Ketchikan.

STATION RECORDS.

FISH CREEK NEAR SEA LEVEL, REVILLAGIGEDO ISLAND.

Location.—In latitude 55° 24′ N., longitude 131° 12′ W., near outlet of Lower Lake on Fish Creek, 600 feet from tidewater at head of Thorne Arm, 2 miles northwest of mine at Sea Level, and 25 miles by water from Ketchikan.

Drainage area.—Not measured.

Records available.—May 19, 1915, to December 31, 1916.

Gage.—Stevens water-stage recorder on right shore of Lower Lake, 200 feet above outlet.

Discharge measurements.—At medium and high stages made from cable across creek, 1 mile upstream from gage and 500 feet above head of Lower Lake; at low stages made by wading at cable. Only one small creek enters Lower Lake, at point opposite gage, between the cable site and control section.

Channel and control.—The lake is about 500 feet wide opposite the gage. Outlet consists of two channels, each about 60 feet wide, separated by an island 40 feet wide. From the lake to tidewater, 200 feet, the creek falls 20 feet. Bedrock exposed at the outlet of the lake forms a well-defined and permanent control.

Extremes of discharge.—Maximum stage recorded during period, 4.94 feet at 3 a. m. October 15, 1915 (discharge, computed from an extension of the rating curve, 4,020 second-feet; revised since published in Bulletin 642); minimum stage recorded, 0.50 foot February 11, 1916 (discharge, 22 second-feet).

Ice.—Lower Lake freezes over, but as gage is set back in the bank ice does not form in well, and the relatively warm water from the lake and the swift current keep the control open.

Accuracy.—Stage-discharge relation practically permanent; affected by brush lodged at control August 23 to December 31. Rating curve used May 19, 1915, to August 23, 1916, well defined below and fairly well defined above 1,500 second-feet. Rating curve used after August 23, 1916, when control was obstructed by brush, defined below 1.5 feet (discharge, 253 second-feet) by discharge measurements made January 25, 1917, at gage height 1.48 feet (discharge, 243 second-feet) and March 2, 1917, at gage height 0.86 foot (discharge, 65 second-feet). Above a stage of 1.50 feet the curve was drawn 0.16 foot above curve applicable when control was not obstructed. Operation of water-stage recorder satisfactory except for periods indicated by breaks in record shown in the footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table mean daily gage heights for regular intervals of day. Results excellent, except for short periods of break in record and for period when control was obstructed by brush, for which they are fair.

There are three large lakes in the upper drainage basin: Big Lake, 2 miles from beach at elevation 275 feet, covers 1,700 acres; Third Lake, 250 acres; and Mirror Lake, at elevation 1,000 feet, 800 acres. Two-thirds of the drainage basin is covered with a thick growth of timber and brush interspersed with occasional patches of beaver swamp and muskeg. Only the tops of the highest mountains are bare. This large area of lake surface and vegetation, notwithstanding the steep slopes and shallow soil, affords a little ground storage and after a heavy precipitation maintains a good run-off. During a dry, hot period in summer, however, after the snow has melted, the flow becomes very low because of lack of ice or glaciers in the drainage basin.

Discharge measurements of Fish Creek near Sea Level during the period May 19, 1915, to Dec. 31, 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
1915.		*Feet.*	*Sec.-ft.*	1916.		*Feet.*	*Sec.-ft.*
May 20	G. H. Canfield	1.48	328	Jan. 26	G. H. Canfield	0.64	42
July 10	.....do	1.01	118	Apr. 6	.....do	1.36	269
Sept. 13	Canfield and Hoyt	1.04	129	13	.....do	2.35	976
Oct. 13	G. H. Canfield	2.53	1,120	July 30	.....do	2.74	1,360
				Aug. 4	Canfield and Brooks	1.46	308

Daily discharge, in second-feet, of Fish Creek near Sea Level for the period May 19, 1915, to Dec. 31, 1916.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1915.								
1	....	270	143	84	127	632	1,010	660
2	....	312	134	78	150	455	1,070	804
3	....	324	134	73	250	346	780	764
4	....	384	130	69	590	329	660	668
5	....	425	127	67	700	362	639	625
6	....	413	124	69	569	351	583	780
7	....	401	124	73	425	334	455	772
8	....	548	124	152	334	488	413	569
9	....	507	124	340	285	764	285	425
10	....	407	120	1,190	235	756	230	334
11	....	351	117	1,720	190	876	199	265
12	....	312	117	1,470	174	876	178	217
13	....	285	112	1,620	143	1,030	340	178
14	....	255	104	1,170	124	1,120	455	154
15	....	250	99	1,060	117	2,510	527	154
16	....	285	96	892	124	3,160	455	158
17	....	296	91	632	130	1,950	500	204
18	....	270	84	474	130	1,230	534	250
19	362	245	82	378	127	999	488	290
20	340	270	78	307	117	1,320	455	329
21	356	660	76	250	112	1,520	494	395
22	356	716	117	204	101	1,220	407	462
23	334	541	178	170	96	884	362	437
24	307	413	204	140	91	732	318	425
25	285	340	194	127	94	668	270	340
26	290	285	170	104	166	812	226	285
27	334	245	147	101	235	945	226	340
28	362	199	127	107	445	1,120	260	275
29	351	178	112	104	945	1,170	312	226
30	307	158	96	96	900	884	520	204
31	275	....	91	96	....	772	....	182

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1916.												
1	158	34	142	264	362	678	414	694	143	421	610	447
2	143	31	123	280	351	694	402	518	130	318	486	390
3	134	31	111	296	378	774	384	408	119	240	414	318
4	124	30	106	318	512	734	408	334	112	202	362	280
5	114	28	116	302	686	618	460	290	107	187	395	227
6	107	27	119	285	718	618	492	254	107	187	434	194
7	102	26	126	499	567	595	447	228	159	179	402	190
8	91	25	142	532	428	567	402	210	296	162	434	172
9	84	23	275	553	351	518	373	192	368	146	390	162
10	76	22	428	492	302	434	368	180	480	132	318	166
11	73	22	428	454	269	408	408	172	595	122	249	187
12	71	35	351	670	269	434	414	165	480	114	202	179
13	69	204	285	983	264	492	378	157	351	162	169	166
14	67	190	238	938	264	726	368	161	269	356	146	179
15	65	488	220	718	302	983	351	188	209	782	132	218
16	65	1,110	228	532	362	884	340	275	172	553	117	227
17	64	1,170	197	473	428	758	334	302	150	421	132	259
18	64	740	172	395	486	694	324	259	137	334	231	307
19	62	576	165	318	539	581	368	233	140	454	378	259
20	60	724	153	264	662	486	539	329	235	625	766	209
21	58	604	180	233	702	434	610	512	506	518	670	176
22	55	488	176	215	625	428	595	588	454	486	480	146
23	51	407	168	206	499	440	518	798	378	702	351	127
24	48	351	149	210	421	460	408	857	362	625	466	112
25	45	302	142	233	402	473	351	602	567	866	539	100
26	41	260	153	254	447	512	312	428	920	956	473	114
27	40	230	157	302	486	567	290	318	782	956	362	85
28	38	204	153	368	466	567	351	254	902	1,550	334	80
29	38	174	136	384	460	506	750	202	929	1,190	384	91
30	37	....	153	384	525	460	1,300	176	610	956	384	109
31	35	....	206	....	610	....	1,000	159	....	718	....	130

NOTE.—Discharge Sept. 6–12, Nov. 23 to Dec. 1, 1915, Jan. 2–5, Feb. 7–11, 18–29, Oct. 16–30, 1916, estimated, because of gage clock stopping, from maximum and minimum stages indicated by recording pencil, from climatic records, and from comparison of the hydrograph for this station with that for Karta River.

Monthly discharge of Fish Creek near Sea Level for the period May 19, 1915, to Dec. 31, 1916.

Month.	Discharge in second-feet.			Run off (tota in acre-feet).
	Maximum.	Minimum.	Mean.	
1915.				
May 19-31	362	275	328	8,460
June	716	158	352	20,900
July	204	76	122	7,500
August	1,720	67	433	26,600
September	945	91	274	16,300
The period				79,800
1915-16.				
October	3,160	329	988	60,800
November	1,070	178	455	27,100
December	804	154	393	24,200
January	158	35	73.5	4,520
February	1,170	22	295	17,000
March	428	106	190	11,700
April	983	206	412	24,500
May	718	264	456	28,000
June	983	408	584	34,800
July	1,300	290	466	28,700
August	857	159	338	20,700
September	929	107	372	22,200
The year	3,160	22	419	304,000
1916.				
October	1,550	114	504	31,000
November	766	117	374	22,200
December	447	80	196	11,900
The period				65,100

KETCHIKAN CREEK AT KETCHIKAN.

Location.—One-fourth mile below power house of Citizens Light, Power & Water Co., one-third mile northeast of Ketchikan post office, downstream 200 feet from mouth of Schoenbar Creek (entering from right), 1¼ miles from mouth of Granite Basin Creek (entering from left), and 1½ miles from outlet of Ketchikan Lake.

Drainage area.—Not measured.

Records available.—November 1, 1909, to June 30, 1912; June 9, 1915, to December 31, 1916.

Gage.—Vertical staff fastened to a telephone pole near board walk on left bank at bend of creek 200 feet downstream from mouth of Schoenbar Creek; read by employee of the Citizens Light, Power & Water Co. The gage used since June 9, 1915, consists of the standard United States Geological Survey enameled gage section graduated in hundredths, half-tenths, and tenths from zero to 10 feet The original gage established November, 1909, and read until June 30, 1912, is at same location and same datum. It is a staff with graduations painted every tenth.

Discharge measurements.—At medium and high stages from footbridge about 500 feet upstream from gage; measuring section poor, as the bridge makes an angle of 20° with the current, and at high stages the flow is broken by large stumps near left bank and at middle of bridge; at low stages, by wading 50 feet below bridge or at another section 100 feet above gage. The flow of Schoenbar Creek has been added to obtain total flow past gage.

Channel and control.—Gage is located in a large deep pool of still water at a bend in creek. The bed of the stream at the outlet of this pool is a solid rock ledge, which forms an excellent permanent control at the gage.

Extremes of discharge.—Maximum stage recorded during 1916, 5 feet July 29 (discharge, 1,490 second-feet); minimum stage recorded, 0.35 foot in January and February (discharge, 40 second-feet).

1909–1912 and 1915–16: Maximum stage recorded, 8.2 feet December 2, 1911 (discharge, 3,400 second-feet); minimum stage recorded, 0.28 foot September 24, 1915 (discharge, 34 second-feet).

Ice.—Ice forms along banks but control remains open.

Diversions.—A small quantity of water is diverted above the station for the use of the town of Ketchikan, the New England Fish Co., and the Standard Oil Co.

Regulation.—Small timber dam and headgates are located at outlet of Ketchikan Lake. Water diverted through power house is returned to creek above gage but causes very little diurnal fluctuation. During low water the flow is increased by water from the reservoir.

Accuracy.—Stage-discharge relation permanent. Rating curve well defined below and poorly defined above 2,000 second-feet. Gage read once daily. Daily discharge ascertained by applying daily gage heights to rating table. Results fair.

Discharge measurements of Ketchikan Creek at Ketchikan during the period June 9, 1915, to Dec. 31, 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
1915.		*Feet.*	*Sec.-ft.*	1916.		*Feet.*	*Sec.-ft.*
June 9	G. H. Canfield	1.15	145	Jan. 15	Canfield and Gardner	0.35	38
July 17	Drake and Canfield	.60	64	27	G. H. Canfield	.44	50
Sept. 12	Hoyt and Canfield	.43	63	Apr. 13	.....do	3.40	760
Oct. 27	Canfield and Wycoff	2.82	522	July 29	.....do	4.96	1,470
30	.....do	1.58	232	31	.....do	1.87	326
				Dec. 4	C. O. Brown	.81	95

Note.—Discharge of all measurements includes measured or estimated flow of Schoenbar Creek.

Daily discharge, in second-feet, of Ketchikan Creek at Ketchikan for the years ending Sept. 30, 1910–1912 and 1915–16.

Day.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
1909–10.												
1	......	685	79	54	79	40	151	160	262	274	308	220
2	......	553	79	54	230	44	100	160	285	241	1,540	170
3	......	300	60	54	160	......	90	180	262	220	685	142
4	......	200	50	44	180	......	80	180	241	252	332	190
5	......	200	49	79	332	......	72	252	241	382	262	170
6	......	125	44	72	200	......	60	270	200	382	210	160
7	......	86	44	49	125	......	44	296	200	285	200	220
8	......	70	44	60	93	......	70	220	553	252	210	108
9	......	60	40	60	85	220	108	190	523	274	170	100
10	......	49	40	80	86	270	79	241	332	285	142	100
11	......	44	44	252	60	332	44	241	285	332	125	79
12	......	44	44	108	49	464	108	296	285	965	125	79
13	......	44	66	79	45	332	125	436	464	2,040	142	79
14	......	44	274	60	44	296	100	274	584	685	220	66
15	......	44	296	50	40	320	285	436	464	357	220	66
16	......	44	210	40	40	382	210	436	493	241	220	72
17	......	44	134	142	35	553	160	274	464	210	220	180
18	......	44	100	72	35	560	142	262	285	200	220	241
19	......	44	79	60	38	553	108	210	262	190	142	252
20	......	44	54	50	40	382	125	241	285	190	125	200
21	......	44	50	49	40	274	160	274	285	200	125	160
22	......	44	49	45	35	220	210	262	308	493	125	200
23	......	44	44	44	35	142	285	274	262	436	108	151
24	......	44	40	40	35	160	142	274	308	296	93	125
25	......	44	40	35	35	200	125	262	296	464	93	200
26	......	100	40	49	36	142	142	320	308	241	93	170
27	......	200	40	116	38	116	180	523	274	296	160	170
28	......	300	40	66	40	93	210	464	262	220	142	241
29	......	200	79	230	......	142	170	436	285	241	436	493
30	......	108	66	100	......	125	151	382	332	241	464	685
31	......	......	54	72	......	160	......	308	......	210	285	......

Daily discharge, in second-feet, of Ketchikan Creek at Ketchikan for the years ending Sept. 30, 1910–1912 and 1915–16—Continued.

Day.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
1910-11.												
1	436	125	79	296	......	......	72	125	296	296	160	180
2	880	357	66	436	......	......	66	180	274	274	170	190
3	685	252	54	464	......	......	66	296	230	252	160	134
4	493	160	54	493	......	......	66	320	200	241	160	125
5	464	252	54	285	......	......	66	252	296	274	160	125
6	382	151	54	241	......	......	66	190	274	285	151	100
7	320	125	54	125	......	......	66	125	230	285	160	93
8	685	142	66	93	......	......	66	125	382	274	142	100
9	436	108	66	93	......	......	60	357	332	285	125	93
10	332	100	66	93	......	......	49	332	241	296	125	93
11	220	66	79	93	......	......	49	220	1,190	274	125	93
12	151	66	464	93	......	......	49	180	1,010	210	125	93
13	493	464	230	93	......	......	54	170	553	200	125	100
14	436	493	493	......	......	......	54	160	382	200	108	523
15	357	252	1,010	......	......	......	252	241	332	210	108	357
16	252	285	920	......	......	......	220	262	320	220	100	332
17	170	320	523	......	......	......	72	357	274	252	100	220
18	436	200	1,440	......	......	151	125	262	262	262	100	357
19	1,700	108	840	......	......	142	357	220	252	262	100	262
20	720	382	553	......	......	100	880	464	220	262	100	220
21	800	436	262	......	......	86	800	308	230	220	93	180
22	436	382	230	......	......	93	220	220	230	241	93	142
23	382	357	262	......	......	125	180	180	230	1,290	93	134
24	241	262	320	......	......	93	170	200	220	760	93	180
25	220	108	262	......	......	93	151	220	220	436	93	200
26	241	100	274	......	......	79	125	241	230	262	86	230
27	1,290	93	210	......	......	86	108	220	285	200	125	190
28	2,220	66	200	......	......	125	108	200	274	180	180	274
29	584	66	523	......	......	108	108	357	274	170	180	200
30	382	54	553	......	......	125	125	357	274	170	151	151
31	210	......	262	......	......	86	......	382	......	160	170	......
1911-12.												
1	142	125	616	93	285	79	180	93	200	......	......	......
2	125	160	3,400	93	220	79	108	86	180	......	......	......
3	108	125	1,760	86	160	66	125	151	160	......	......	......
4	220	142	553	79	134	66	108	210	125	......	......	......
5	285	160	308	79	125	66	160	252	134	......	......	......
6	409	108	220	79	108	54	170	332	125	......	......	......
7	357	108	464	79	108	54	125	262	142	......	......	......
8	285	108	436	79	180	54	100	170	108	......	......	......
9	180	93	241	72	241	54	93	160	116	......	......	......
10	180	79	262	66	308	54	100	151	86	......	......	......
11	160	66	464	66	320	54	72	160	79	......	......	......
12	160	66	553	66	409	49	79	190	108	......	......	......
13	125	66	332	66	493	49	66	220	116	......	......	......
14	160	54	285	66	584	49	79	252	116	......	......	......
15	220	54	262	66	616	44	79	241	108	......	......	......
16	142	125	170	66	170	44	86	210	108	......	......	......
17	160	262	200	66	142	44	79	200	108	......	......	......
18	125	285	220	66	125	44	79	180	116	......	......	......
19	332	116	210	66	108	44	66	190	108	......	......	......
20	200	116	200	86	108	44	66	190	108	......	......	......
21	160	108	241	436	308	44	66	200	108	......	......	......
22	125	220	230	332	180	44	66	180	116	......	......	......
23	125	464	210	180	125	44	66	180	93	......	......	......
24	125	409	180	200	125	44	66	160	93	......	......	......
25	125	308	125	436	160	40	66	180	93	......	......	......
26	108	230	108	241	125	44	66	200	86	......	......	......
27	108	220	100	220	93	200	93	190	86	......	......	......
28	108	180	100	262	93	108	125	142	79	......	......	......
29	108	220	93	230	66	66	79	125	79	......	......	......
30	93	285	93	220	......	93	142	160	79	......	......	......
31	93	......	93	436	......	108	......	180	......	......	......	......

Daily discharge, in second-feet, of Ketchikan Creek at Ketchikan for the years ending Sept. 30, 1910–1912 and 1915–16—Continued.

Day.	July.	Aug.	Sept.	Day.	July.	Aug.	Sept.	Day.	July.	Aug.	Sept.
1915.				1915.				1915.			
1	85	59	332	11	102	880	54	21	59	46	38
2	85	59	553	12	85	523	48	22	200	46	36
3	82	61	584	13	79	553	44	23	108	46	34
4	79	54	220	14	74	285	42	24	79	44	34
5	87	44	118	15	71	1,920	54	25	66	41	66
6	85	41	79	16	66	308	46	26	66	41	56
7	108	66	87	17	66	125	42	27	64	41	41
8	200	464	102	18	61	102	41	28	61	41	56
9	142	382	79	19	61	71	41	29	59	41	79
10	125	2,640	61	20	61	64	39	30	59	41	85
								31	59	262	......

Day.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
1915–16.												
1	71	241	523	80	40	74	190	142	296	200	436	79
2	54	210	553	72	40	66	118	142	262	190	190	79
3	79	220	523	69	40	61	122	142	274	180	142	76
4	220	296	436	66	40	64	122	210	274	200	108	74
5	108	357	296	66	40	64	122	274	332	220	105	125
6	85	285	357	60	40	64	108	357	285	200	106	241
7	66	200	241	57	40	64	111	252	252	180	102	357
8	274	190	170	54	40	90	200	170	308	180	99	308
9	180	160	115	51	40	409	210	122	200	160	102	210
10	160	108	102	47	40	180	200	87	142	285	102	523
11	274	102	85	43	40	142	200	85	200	332	99	274
12	274	79	59	40	80	118	200	105	200	262	96	170
13	840	553	54	40	200	99	230	93	220	200	93	108
14	308	464	61	40	616	79	436	90	274	160	96	99
15	1,540	308	64	40	436	85	262	102	262	200	93	93
16	1,010	553	108	40	142	102	151	142	262	180	96	90
17	382	308	90	40	120	85	142	220	262	190	90	87
18	493	308	160	40	100	76	125	285	252	180	82	90
19	241	230	170	40	100	105	122	357	210	262	79	93
20	685	190	200	40	100	111	115	523	200	230	357	200
21	760	285	200	40	100	102	90	332	200	200	357	241
22	436	241	220	40	100	108	82	252	200	200	523	262
23	262	180	200	40	100	96	93	200	180	170	357	274
24	285	200	200	40	100	105	99	142	200	125	332	357
25	296	180	160	40	100	108	111	151	252	134	210	523
26	296	142	102	45	80	102	122	180	285	125	200	493
27	285	102	96	48	80	85	125	200	285	142	108	274
28	493	108	85	45	80	76	134	200	241	357	93	553
29	523	252	85	40	80	76	160	200	230	1,060	102	296
30	241	93	82	40	......	200	151	200	200	1,010	87	200
31	285	......	82	40	......	200	......	210	......	1,010	82	......

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1916.				1916.				1916.			
1	108	262	180	11	79	93	108	21	210	180	85
2	90	285	115	12	82	87	105	22	308	142	82
3	82	296	118	13	180	71	76	23	357	170	66
4	79	200	93	14	840	76	241	24	308	262	64
5	76	262	111	15	332	79	125	25	382	200	64
6	71	262	74	16	180	85	82	26	436	180	66
7	71	220	170	17	170	90	160	27	493	220	74
8	69	210	180	18	200	142	190	28	523	210	71
9	66	170	125	19	252	409	87	29	382	180	69
10	69	142	111	20	308	650	85	30	241	190	69
								31	190	......	170

NOTE.—No gage readings Nov. 3–5, 8, 13–15, 17, 20, 21, 23–26, 28, 29, Dec. 3, 4, 6, 7, 9, 21, 25, 26, and 28, 1909; Jan. 2, 10, 14, 15, 19, 20, 22, 24, Feb. 9, 11, 13, 15, 19, 26–28, Mar. 1, 3–8, 10, 15, 18, 24, Apr. 3, 4, 6, 8, 16, 21, and May 6, 1910; discharge estimated. Discharge estimated from climatic records as follows: Jan. 14 to Mar. 17, 1911; Jan. 2–14, 16–26, Jan. 28 to Feb. 13, and Feb. 17–29, 1916. Estimates of discharge Nov. 1, 1909, to June 30, 1912, and June 9, 1915, to Feb. 29, 1916, differ from that published in Bulletin 642 because of a revision of rating curve, based upon discharge measurements made in 1916.

Monthly discharge of Ketchikan Creek at Ketchikan for the years ending Sept. 30, 1910–1912 and 1915–16.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
1909–10.				
November	685	44	130	7,740
December	296	40	76.5	4,700
January	252	36	76.3	4,690
February	332	36	82.0	4,550
March	560	40	237	14,600
April	285	44	135	8,030
May	523	160	291	17,900
June	584	200	330	19,600
July	2,040	190	374	23,000
August	1,540	93	256	15,700
September	685	66	183	10,900
The period	....	....	....	131,000
1910–11.				
October	2,220	151	550	33,800
November	493	54	211	12,600
December	1,440	54	339	20,800
January	493	....	125	7,690
February	....	....	70	3,890
March	....	....	100	6,150
April	880	49	162	9,640
May	464	125	249	15,300
June	1,190	200	334	19,900
July	1,290	160	297	18,300
August	180	86	128	7,870
September	523	93	189	11,200
The year	2,220	....	231	167,000
1911–12.				
October	409	93	173	10,600
November	464	54	169	10,100
December	3,400	93	411	25,300
January	436	66	151	9,280
February	616	66	214	12,300
March	200	40	62.1	3,820
April	180	66	95.2	5,660
May	332	86	187	11,500
June	200	79	112	6,660
The period	....	....	....	95,200
1951.				
July	200	59	86.6	5,320
August	2,640	41	303	18,600
September	584	34	106	6,310
The period	....	....	....	30,200
1915–16.				
October	1,540	54	371	22,800
November	553	79	238	14,200
December	553	54	190	11,700
January	80	40	47.8	2,940
February	616	40	109	6,270
March	409	61	110	6,760
April	436	82	155	9,220
May	523	85	199	12,200
June	332	142	241	14,300
July	1,060	125	281	17,300
August	523	79	165	10,100
September	553	74	228	13,600
The year	1,540	40	195	141,000
1916.				
October	840	66	233	14,300
November	650	71	201	12,000
December	241	64	110	6,760
The period	....	....	....	33,100

NOTE.—See footnote to daily-discharge table.

SWAN LAKE OUTLET AT CARROLL INLET, REVILLAGIGEDO ISLAND.

Location.—Halfway between Swan Lake and tidewater; on east shore of Carroll Inlet, 1 mile from its head; 30 miles by water from Ketchikan.

Drainage area.—Not measured.

Records available.—August 24 to December 31, 1916.

Gage.—Stevens water-stage recorder on left bank, half a mile from tidewater; reached by a trail which leaves beach back of old cabin one-fourth mile south of mouth of creek.

Discharge measurements.—At medium and high stages, made from a cable across stream 100 feet downstream from gage; at low stages made by wading.

Channel and control.—The gage well is in a deep pool 25 feet upstream from a contracted portion of channel, where a fall of a foot over bed rock forms a permanent control. The effect of the violent fluctuation of the water surface outside of gage well is decreased in the inner float well because the intake holes at the bottom are very small. At the cable section the bed is rough, the water shallow, and the current very swift. Point of zero flow is at gage height 0.0±0.2 foot.

Extremes of discharge.—Maximum stage recorded during period, 4.74 feet at 7 p. m. October 28 (discharge, 1,210 second-feet); minimum stage recorded, 1.23 feet December 28 (discharge, 73 second-feet).

Ice.—Stage-discharge relation not affected by ice.

Accuracy.—Stage-discharge relation permanent. Rating curve fairly well defined between 50 and 900 second-feet. Operation of water-stage recorder satisfactory except December 8–31. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph. Results fair.

Swan Lake, whose area is about 350 acres, is 1½ miles from tidewater, at an elevation of 225 feet above sea level.

Discharge measurements of Swan Lake outlet at Carroll Inlet during period Aug. 24 to Dec. 31, 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Aug. 24	G. H. Canfield	3.40	726	Dec. 8	C. O. Brown	1.75	238
Nov. 1	C. T. Gardner	2.84	612				

Daily discharge, in second-feet, of Swan Lake outlet at Carroll Inlet for the period Aug. 24 to Dec. 31, 1916.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1		213	452	568	394	16		226	666	151	201
2		198	347	485	337	17		198	485	98	216
3		177	278	452	291	18		186	375	414	238
4		159	238	407	260	19		207	502	449	216
5		154	244	414	216	20		334	683	617	201
6		168	235	410	183	21		568	634	551	171
7		356	207	394	180	22		468	534	426	142
8		568	180	423	171	23		414	716	334	114
9		534	156	378	156	24	766	394	650	340	88
10		700	139	313	142	25	600	666	749	398	81
11		700	131	254	171	26	468	918	816	310	88
12		568	134	210	156	27	391	749	749	325	84
13		430	229	180	156	28	334	816	1,090	303	77
14		334	446	159	142	29	294	816	1,020	325	88
15		269	850	159	171	30	260	617	799	356	88
						31	238		650		101

Note.—Discharge Dec. 8–31 estimated from maximum and minimum stages indicated by recording pencil and comparison with gage-height graph for Fish Creek near Sea Level.

Monthly discharge of Swan Lake outlet at Carroll Inlet for the period Aug. 24 to Dec. 31, 1916.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
August 24-31	766	238	419	6,650
September	918	154	437	26,000
October	1,090	131	496	30,500
November	617	98	353	21,000
December	394	77	172	10,600
The period				94,800

ORCHARD LAKE OUTLET AT SHRIMP BAY, REVILLAGIGEDO ISLAND.

Location.—In latitude 55° 50′ N., longitude 131° 27′ W., at outlet of Orchard Lake, one-third mile from tidewater at head of Shrimp Bay, an arm of Behm Canal, 46 miles by water from Ketchikan.

Drainage area.—Not measured.

Records available.—May 28, 1915, to December 31, 1916.

Gage.—Stevens water-stage recorder on right bank 300 feet below Orchard Lake and 100 feet above site of timber-crib dam, which was built in 1914 for proposed pulp mill and washed out by high water August 10, 1915. Datum of gage lowered 2 feet September 15, 1915. Gage heights May 29 to August 10 referred to first datum; August 11, 1915, to August 17, 1916, to second datum. Datum of gage lowered 1 foot August 17, 1916. Gage heights August 18 to December 31, 1916, referred to this datum.

Discharge measurements.—At medium and high stages made from cable 50 feet downstream from gage; at low stages by wading near cable.

Channel and control.—From Orchard Lake, at elevation 134 feet above high tide, the stream descends in a series of rapids for 1,000 feet through a narrow gorge, then divides into two channels and enters the bay in two cascades of 100-foot vertical fall. Opposite the gage the water is deep and the current sluggish. At the site of the old dam bedrock is exposed, but for 30 feet upstream the channel is filled in with loose rock and brush placed during construction of dam. This material forms a riffle which acts as a control for water surface at gage at low and medium stages and is scoured down when ice goes out of lake; the rock outcrop at site of old dam acts as a control at high stages and is permanent.

Extremes of discharge.—Maximum stage recorded during period, 8.4 feet at 2 a. m. October 16, 1915 (discharge, 6,230 second-feet); minimum, estimated, 20 second-feet February 11, 1916.

Ice.—Ice forms on Orchard Lake, but because of swift current and relatively warm water from lake the outlet and control remain open.

Accuracy.—Stage-discharge relation changed August 10, 1915, when timber dam below gage was washed out, and changed for low stages February 15 and April 13, when the old gravel cofferdam under cable was scoured down by ice passing out of lake. Fifteen discharge measurements were made during period, by means of which rating curves have been constructed applicable as follows: May 28 to August 10 well-defined below and poorly defined above 2,000 second-feet; August 11, 1915, to February 14, 1916, well defined; February 15 to April 12, poorly defined; April 13 to December 31, 1916, fairly well defined. Operation of water-stage recorder satisfactory, except for periods when clock stopped, as shown in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights, determined by inspecting gage-height graph, or for days of considerable fluctuation by averaging the discharge for equal intervals of the day, except April 13 to November 2, 1916, for which the daily discharge was ascertained by use of the discharge integrator. Results fair.

The highest mountains on this drainage basin are only 3,500 feet above sea level and are covered to an elevation of 2,500 feet by a heavy stand of timber and a thick undergrowth of brush, ferns, alders, and devil's club. The topography is not so rugged as that of the area surrounding Shelockum Lake, and the proportion of vegetation, soil cover, and lake area is greater, so that more water is stored and the flow in the Orchard Lake drainage basin is better sustained.

Discharge measurements of Orchard Lake outlet at Shrimp Bay for the period May 28, 1915, to Dec. 31, 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
1915.		*Feet.*	*Sec.-ft.*	1916.		*Feet.*	*Sec.-ft.*
May 29	G. H. Canfield	2.88	444	Jan. 20	G. H. Canfield	−0.34	36
July 8	.....do	1.96	248	Mar. 15	.....do	.43	156
Aug. 7	Gardner and Williams	.90	145	Apr. 18	.....do	1.51	473
Sept. 15	Canfield and Hoyt	[a] 1.40	341	18	.....do	1.50	469
16	.....do	1.71	428	Aug. 18	.....do	[b] 1.92	314
Oct. 16	G. H. Canfield	7.58	5,280	Nov. 3	Gardner and Smith	2.35	507
16	.....do	6.78	4,270	Dec. 7	C. O. Brown	1.33	173
17	.....do	5.22	2,720				

[a] Datum of gage lowered 2 feet before making discharge measurement.
[b] Datum of gage lowered 1 foot before making discharge measurement.

Daily discharge, in second-feet, of Orchard Lake outlet at Shrimp Bay for the period May 28, 1915, to Dec. 31, 1916.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1915.								
1	....	362	271	170	159	640	1,260	320
2	....	362	271	161	239	406	1,000	974
3	....	373	280	151	488	299	710	1,130
4	....	422	263	145	610	372	710	930
5	....	450	263	135	570	478	690	690
6	....	495	271	134	453	385	630	975
7	....	580	263	146	374	336	551	944
8	....	620	252	240	310	806	460	611
9	....	528	242	792	257	1,280	412	403
10	....	480	227	3,480	208	930	382	299
11	....	480	219	4,700	188	1,400	382	232
12	....	495	209	2,550	180	1,260	368	192
13	....	480	202	1,980	159	1,520	570	157
14	....	436	196	1,200	161	1,300	710	138
15	....	450	193	1,250	317	4,140	532	124
16	....	800	194	1,020	427	4,990	421	135
17	....	700	197	616	368	2,430	444	142
18	....	580	191	418	329	1,170	551	174
19	....	480	183	334	276	830	460	208
20	....	465	178	272	232	1,260	412	283
21	....	700	176	228	202	1,320	525	434
22	....	680	262	198	178	1,010	444	450
23	....	545	385	178	155	880	346	403
24	....	465	373	159	138	930	344	354
25	....	410	318	150	232	955	336	290
26	....	410	271	142	354	1,570	294	235
27	....	350	248	136	385	1,260	241	232
28	465	308	224	133	1,010	1,840	204	214
29	450	280	208	126	1,720	1,480	218	174
30	422	271	195	133	1,090	951	239	157
31	373	....	183	198	....	805	....	140

Daily discharge, in second-feet, of Orchard Lake outlet at Shrimp Bay for the period May 28, 1915, to Dec. 31, 1916—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1916.												
1	122	29	168	341	673	1,430	694	1,490	198	516	516	488
2	118	28	159	394	704	1,370	700	1,030	185	370	452	379
3	116	28	150	440	838	1,430	615	595	173	285	426	297
4	112	27	142	460	888	1,080	656	463	160	233	412	266
5	108	25	133	421	844	870	832	437	150	258	406	223
6	103	24	126	380	858	828	928	404	158	291	429	191
7	98	23	118	650	728	783	756	376	360	252	406	173
8	94	22	110	630	566	783	658	366	845	214	467	162
9	88	22	206	570	472	789	619	347	818	186	443	149
10	84	21	322	517	446	894	610	328	1,040	160	357	140
11	79	20	290	453	438	944	628	317	1,070	146	282	179
12	75	62	243	548	434	1,130	555	304	761	148	230	179
13	70	150	206	1,380	434	1,270	665	294	518	258	195	163
14	65	240	174	1,100	514	1,520	870	288	378	443	278	162
15	60	813	155	754	687	1,560	653	378	296	1,320	179	227
16	54	1,070	155	560	890	1,360	575	409	234	886	181	225
17	48	685	145	522	1,020	1,240	559	359	207	559	238	208
18	43	514	132	481	1,050	1,130	530	309	182	396	522	234
19	41	760	121	421	1,100	888	831	289	230	452	522	234
20	37	1,150	116	369	1,020	764	1,750	350	408	849	748	199
21	36	810	136	358	910	780	1,900	677	892	929	628	165
22	36	610	157	344	776	839	1,380	768	648	701	446	142
23	36	450	163	340	670	866	1,020	1,020	508	951	346	122
24	35	363	152	375	656	900	760	990	485	785	348	108
25	35	324	143	470	758	968	659	660	728	980	434	97
26	35	294	150	543	978	1,080	645	487	1,200	1,200	418	87
27	34	261	161	720	988	1,160	646	383	916	1,010	354	82
28	34	232	163	918	822	1,060	728	316	926	1,600	330	78
29	33	204	154	846	966	988	1,730	274	1,130	1,480	390	73
30	32	....	163	746	1,160	753	2,110	246	781	916	415	84
31	30	....	250	....	1,350	....	1,370	221	....	654	....	91

NOTE.—Discharge estimated (no gage record) for following periods: Aug. 22 to Sept. 2, from climatic records and flow before and after the period· Nov. 3–16, 1915, from climatic records and minimum stage indicated by recorder; Jan. 3 to Feb. 13, from climatic records and one current-meter measurement; Mar. 2–8, because water surface was below bottom of well, and July 13–17, 19–31, Aug. 1, 2, 15, and 16, 1916, from climatic records and comparison with records of flow for Shelockum Lake outlet.

Monthly discharge of Orchard Lake outlet at Shrimp Bay for period June 1, 1915, to Dec. 31, 1916.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
1915.				
June	800	271	482	28,700
July	385	176	239	14,700
August	4,700	126	699	43,000
September	1,720	138	392	23,300
The period	....	....	....	110,000
1915–16.				
October	4,990	299	1,270	78,100
November	1,260	204	495	29,500
December	1,130	124	392	24,100
January	122	30	64.2	3,950
February	1,150	20	319	18,300
March	322	110	167	10,300
April	1,380	340	568	33,800
May	1,350	434	795	48,900
June	1,560	753	1,050	62,500
July	2,110	530	891	54,800
August	1,490	221	490	30,100
September	1,200	150	553	32,900
The year	4,990	20	588	427,000
1916.				
October	1,600	146	627	38,600
November	748	179	393	23,400
December	488	73	181	11,100
The period	....	....	....	73,100

SHELOCKUM LAKE OUTLET AT BAILEY BAY.

Location.—In latitude 56° 00′ N., longitude 131° 36′ W. on mainland near outlet of Shelockum Lake, three-fourths mile by Forest Service trail from tidewater at north end of Bailey Bay, and 52 miles by water north of Ketchikan.

Drainage area.—18 square miles (measured on sheets Nos. 5 and 8 of the Alaska Boundary Tribunal, edition of 1895).

Records available.—June 1, 1915, to December 31, 1916.

Gage.—Stevens water stage recorder on right shore of lake, 250 feet above outlet.

Discharge measurements.—Made from cable across outlet of lake, 200 feet below gage and 50 feet upstream from crest of falls.

Channel and control.—Opposite the gage the lake is 600 feet wide; at the outlet bedrock is exposed and the water makes a nearly perpendicular fall of 150 feet. This fall forms an excellent and permanent control for the gage. At extremely high stages the lake has another outlet about 200 feet to left of main outlet. Point of zero flow is at gage height 0.6 foot.

Extremes of discharge.—Maximum stage recorded during period, 6.5 feet (estimated) October 15, 1915 (discharge, 2,440 second-feet); minimum flow, estimated from gage record and climatic data, 9 second-feet February 11, 1916.

Ice.—Ice forms on Shelockum Lake and at gage, but because of the swift current and relatively warm water from lake, the control remains open and stage-discharge relation is not affected by ice.

Accuracy.—Stage-discharge relation permanent. Rating curve well defined. Operation of water-stage recorder satisfactory except for periods of break in record shown in the footnote to daily-discharge table. Daily discharge ascertained by applying to the rating table mean daily gage heights determined by inspection of gage-height graph, or, for days of considerable fluctuation, by averaging the discharge for equal intervals of the day, except March 27 to November 1, 1916 for which discharge was ascertained by use of discharge integrator. Results excellent except for periods of break in record, for which they are fair.

Shelockum Lake, at elevation 344 feet, is only 350 acres in area. The drainage basin above the lake is rough and precipitous and is covered with little soil or vegetation. There are no glaciers or ice fields at the source of the tributary streams. Therefore, as there is little natural storage, the run-off after a heavy rainfall is rapid and not well sustained, and during a hot, dry summer the flow becomes very low. The large amount of snow that accumulates during the winter months maintains a good flow.

Discharge measurements of Shelockum Lake outlet at Bailey Bay, during the period June 1, 1915, to Dec. 31, 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
1915		*Feet.*	*Sec.-ft.*	1915.		*Feet.*	*Sec.-ft.*
June 4[a]	G. H. Canfield	2.78	294	Oct. 15	G. H. Canfield	6.32	2,280
July 9	do	1.78	87	17	do	3.47	484
Aug. 6	Gardner and Williams	1.20	22.5				
Sept. 14	Canfield and Hoyt	1.35	42	1916.			
15	do	1.75	86	Apr. 18	do	1.90	103

[a] Measurement made from boat at cable section.

Daily dischage, in second-feet, of Shelockum Lake outlet at Bailey Bay, for the period June 1, 1915, to Dec. 31, 1916.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1915.												
1	......	......	......	......	......	325	91	27	......	......	480	94
2	......	......	......	......	......	310	91	24	......	......	334	222
3	......	......	......	......	......	300	90	23	......	......	248	268
4	......	......	......	......	......	295	85	21	......	......	258	245
5	......	......	......	......	......	278	91	20	......	......	241	200
6	......	......	......	......	......	265	102	25	......	......	191	250
7	......	......	......	......	......	312	109	45	......	......	144	280
8	......	......	......	......	......	352	96	......	......	......	104	187
9	......	......	......	......	......	270	87	......	......	......	83	125
10	......	......	......	......	......	222	77	......	......	......	69	88
11	......	......	......	......	......	216	69	......	......	......	63	70
12	......	......	......	......	......	216	60	......	......	......	57	55
13	......	......	......	......	......	206	55	......	......	......	86	47
14	......	......	......	......	......	185	50	......	39	......	175	45
15	......	......	......	......	......	198	47	......	77	2,220	179	41
16	......	......	......	......	......	255	42	......	94	1,030	158	50
17	......	......	......	......	......	227	40	......	99	510	156	55
18	......	......	......	......	......	187	36	......	96	347	177	61
19	......	......	......	......	......	158	33	......	81	250	154	64
20	......	......	......	......	......	258	31	......	75	338	127	70
21	......	......	......	......	......	448	31	......	......	379	121	90
22	......	......	......	......	......	325	49	......	......	325	110	101
23	......	......	......	......	......	232	63	......	......	262	91	91
24	......	......	......	......	......	179	65	......	......	320	97	84
25	......	......	......	......	......	166	60	......	......	339	102	70
26	......	......	......	......	......	158	53	......	......	580	88	61
27	......	......	......	......	......	131	48	......	......	450	83	65
28	......	......	......	......	......	113	43	......	......	620	72	58
29	......	......	......	......	......	102	38	......	......	456	71	48
30	......	......	......	......	......	94	33	......	......	288	69	46
31	......	......	......	......	......	......	31	......	......	292	......	45
1916.												
1	39	12	51	96	220	530	270	458	49	162	166	134
2	33	11	49	110	245	486	270	385	43	112	144	107
3	31	11	48	152	295	610	253	264	39	81	120	84
4	29	11	47	160	379	442	262	195	37	71	104	78
5	29	11	46	141	318	374	282	168	46	98	120	71
6	28	11	45	119	268	438	300	152	118	91	138	63
7	27	10	44	151	216	386	258	146	290	75	138	61
8	24	10	43	168	164	329	252	136	438	63	179	59
9	23	10	84	166	136	267	247	120	345	54	156	53
10	22	10	142	166	134	242	266	114	528	46	115	52
11	21	9	107	146	131	328	284	106	379	44	87	51
12	21	22	71	148	132	410	260	98	231	75	69	45
13	21	107	59	333	138	450	252	90	150	246	57	44
14	19	172	55	291	158	712	307	108	103	413	51	52
15	19	393	54	199	218	718	277	130	80	602	70	75
16	18	407	53	149	302	532	256	136	64	354	70	70
17	17	183	52	134	352	483	268	120	55	211	107	69
18	17	120	48	126	379	450	314	96	64	140	202	73
19	19	227	46	106	393	359	428	118	115	274	206	67
20	21	450	44	93	366	323	594	229	270	540	234	58
21	20	325	45	90	366	315	599	473	378	454	183	52
22	19	216	47	87	302	330	383	371	260	320	134	46
23	16	136	48	81	250	332	272	478	210	375	105	38
24	16	96	46	96	234	352	206	436	204	305	97	35
25	15	67	44	134	162	384	182	272	455	392	110	32
26	14	60	44	162	347	455	178	181	600	455	109	31
27	14	57	48	217	352	502	179	130	358	359	91	30
28	14	54	48	281	308	462	223	100	427	565	85	28
29	13	51	49	275	379	391	769	83	386	448	91	30
30	13	......	49	238	480	325	755	69	252	287	110	35
31	13	......	67	......	536	......	413	58	......	200	......	41

NOTE.—June 1-3, discharge estimated; Aug. 8 to Sept. 14, Sept. 21 to Oct. 4, 1915, and July 1-8, 1916, gage clock stopped; discharge estimated from maximum and minimum stages indicated by the recorder and by a comparison of the record for this station with that for Orchard Lake outlet. Jan. 23 to Mar. 13, ice in well; discharge estimated from climatic records at Ketchikan and by a comparison of hydrograph for this station with that for Orchard Lake outlet. Estimates of discharge below 91 second-feet, June 1, 1915, to Feb. 21, 1916, differ from that published in Bulletin 642 because of a revision of the rating curve.

Monthly discharge of Shelockum Lake outlet at Bailey Bay for 1915–16.

[Drainage area, 18 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
1915.						
June	448	94	233	12.9	14.39	13,900
July	109	31	61.2	3.40	3.92	3,760
August			129	7.17	8.27	7,930
September			101	5.61	6.26	6,010
The period						31,600
1915–16.						
October	2,220		401	22.3	25.71	24,700
November	480	57	146	8.11	9.05	8,690
December	280	41	106	5.89	6.79	6,520
January	39	13	20.8	1.16	1.34	1,280
February	450	9	112	6.22	6.71	6,440
March	142	43	55.6	3.09	3.56	3,420
April	333	81	160	8.89	9.92	9,520
May	536	131	279	15.5	17.87	17,200
June	718	242	424	23.6	26.33	25,200
July	769	178	324	18.0	20.75	19,900
August	478	58	194	10.8	12.45	11,900
September	600	37	232	12.9	14.39	13,800
The year	2,220	9	205	11.4	154.87	149,000
1916.						
October	602	44	255	14.2	16.37	15,700
November	234	51	122	6.78	7.56	7,260
December	134	28	56.9	3.16	3.64	3,500
The period						26,500

KARTA RIVER AT KARTA BAY, PRINCE OF WALES ISLAND.

Location.—In latitude 55° 34′ N., longitude 132° 37′ W., at head of Karta Bay, an arm of Kasaan Bay, on east coast of Prince of Wales Island, 42 miles by water across Clarence Strait from Ketchikan.

Drainage area.—49.5 square miles (U. S. Forest Service reconnaissance map of Prince of Wales Island, 1914).

Records available.—July 1, 1915, to December 31, 1916.

Gage.—Stevens water-stage recorder on left bank, half a mile above tidewater, at head of Karta Bay and 1½ miles below outlet of Little Salmon Lake. Two per cent of total drainage of Karta River enters between outlet of lake and gage.

Discharge measurements.—At medium and high stages made from cable across river 50 feet upstream from gage; at low stages by wading at cable section.

Channel and control.—From Little Salmon Lake, 1½ miles from tidewater, the river descends 105 feet in a series of rapids in a wide, shallow channel, the banks of which are low but do not overflow. The bed is of course gravel and boulders; rock crops out only at outlet of lake. Gage and cable are at a pool of still water formed by a riffle of coarse gravel that makes a well-defined and permanent control.

Extremes of discharge.—Maximum stage recorded during period, 4.4 feet, October 16 (discharge, 3,340 second-feet); minimum flow, estimated from discharge measurement, gage record, and climatic data, 21 second-feet, February 11.

Ice.—Stage-discharge relation affected by ice.

ACCURACY.—Stage-discharge relation practically permanent, except when affected by ice January 8 to February 16. Rating curve well defined between 80 and 1,500 second-feet; extended below 80 second-feet to the point of zero flow and above 1,500 second-feet by estimation. Operation of water-stage recorder satisfactory except for periods indicated by breaks in record as shown in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or for days of considerable fluctuation by averaging results obtained by applying to rating table mean gage heights for regular intervals of day. Results excellent except for periods of break in record, for period affected by ice, and for discharge above 1,500 second-feet, for which they are fair.

The combined area of Little Salmon Lake at elevation 105 feet, and Salmon Lake at elevation 110 feet, is 1,600 acres. The slopes along the right shore of lakes and at head of Salmon Lake are gentle, and the area included by the 250-foot contour above lake outlet is 5,500 acres. The drainage area to elevation 2,000 feet is heavily covered with timber and dense undergrowth of ferns, brush, and alders. The upper parts of the mountains are covered with thin soil and brush. Only a few peaks at an elevation of 3,500 feet are bare. This large lake and flat area and thick vegetal cover afford considerable natural storage, which, after heavy precipitation, maintains a good run-off. The snow usually melts by the end of June, and the run-off becomes very low during a dry, hot summer.

The Forest Service in summer of 1916 constructed a pack trail from tidewater to outlet of Little Salmon Lake.

Discharge measurements of Karta River at Karta Bay during the period July 1, 1915, to Dec. 31, 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
1915.		*Feet.*	*Sec.-ft.*	1916.		*Feet.*	*Sec.-ft.*
July 6	G. H. Canfield	....	90	Jan. 29	G. H. Canfield	[a]1.45	31
16	.....do	1.00	85	Feb. 29	.....do	1.38	229
Sept. 7	.....do	1.49	283	May 18	.....do	2.06	680
17	Canfield and Hoyt	1.06	109				
Oct. 20	G. H. Canfield	2.94	1,500				

[a] Stage-discharge relation affected by ice.

Daily discharge, in second-feet, of Karta River at Karta Bay for the period July 1, 1915, to Dec. 31, 1916.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1915.							1915.						
1	......	48	150	540	1,920	1,020	16	88	695	109	3,000	960	351
2	......	46	200	385	1,340	1,330	17	88	524	103	1,960	870	375
3	......	44	300	290	1,000	1,540	18	83	419	100	1,240	843	475
4	......	44	400	285	987	1,330	19	76	328	91	1,150	671	601
5	......	44	510	305	1,000	1,390	20	74	268	88	1,490	653	852
6	......	44	350	296	834	1,980	21	69	220	81	1,310	987	987
7	......	118	283	258	631	1,860	22	74	184	78	1,010	852	915
8	......	356	278	416	489	1,100	23	76	156	76	1,000	843	738
9	......	695	253	650	375	720	24	76	135	71	1,050	746	679
10	......	1,200	215	643	316	517	25	71	121	74	960	655	531
11	......	1,080	180	750	299	387	26	66	112	120	1,170	531	428
12	......	1,170	160	750	278	305	27	64	97	197	1,170	440	433
13	......	1,170	138	882	1,090	253	28	60	88	360	1,620	432	363
14	......	1,130	125	1,000	1,680	215	29	58	81	830	1,460	789	305
15	......	987	115	2,120	1,400	206	30	54	88	770	1,050	754	268
							31	52	135	......	1,350	......	238

Daily discharge, in second-feet, of Karta River at Karta Bay for the period July 1, 1915, to Dec. 31, 1916—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1916.												
1	206	30	201	382	480	565	344	314	112	410	565	1,010
2	172	29	176	441	480	625	320	285	97	320	515	748
3	152	29	156	494	387	550	290	243	88	244	970	625
4	138	29	142	494	522	515	274	210	88	215	1,370	572
5	128	27	135	448	558	515	280	176	81	188	1,480	460
6	121	27	125	460	657	480	290	156	76	168	1,120	363
7	112	26	121	681	565	448	280	142	142	149	799	332
8	106	26	118	714	467	415	259	128	180	132	773	290
9	106	24	176	764	402	370	243	118	201	121	673	248
10	103	22	248	681	363	350	259	115	274	112	529	264
11	103	21	243	602	326	363	320	103	320	103	422	376
12	100	32	220	730	376	428	344	100	302	94	338	370
13	100	172	192	1,510	408	515	314	94	264	125	280	326
14	100	132	172	1,370	422	689	280	88	224	217	248	428
15	97	278	172	1,000	448	657	264	88	188	480	264	595
16	97	580	197	730	508	610	264	86	164	474	254	501
17	94	679	176	618	590	580	269	83	145	389	467	515
18	88	566	156	515	673	536	259	83	142	332	764	610
19	83	608	156	454	665	487	280	88	172	402	764	536
20	81	679	156	543	649	441	290	106	248	448	871	474
21	74	566	188	565	595	415	290	149	370	515	730	396
22	71	447	254	515	522	396	290	172	344	550	572	320
23	66	363	254	529	441	396	259	269	308	730	454	264
24	60	334	224	494	408	402	229	338	280	673	793	220
25	54	328	290	487	422	422	210	308	363	808	1,000	188
26	48	299	296	474	487	460	184	259	665	835	799	168
27	44	273	290	501	480	480	176	224	665	934	756	152
28	39	253	243	565	467	467	172	188	730	1,680	739	142
29	32	224	220	565	480	434	290	160	681	1,450	714	135
30	30	....	248	522	513	382	376	142	529	970	888	145
31	30	....	338	....	550	....	350	125	....	730	....	160

NOTE.—Discharge July 1-15, 1915, estimated at 95 second-feet from one discharge measurement and from a comparison of hydrograph for this station with that for Fish Creek. Discharge Jan. 8 to Feb. 16, 1916, estimated because of ice; Sept. 1-6, Sept. 23 to Oct. 18, 1915, May 17 and May 30 to June 14, 1916, estimated because of clock stopping, from maximum and minimum stages indicated by recorder and from a comparison of record for this station with that for Fish Creek.

Monthly discharge of Karta River at Karta Bay for the period July 1, 1915, to Dec. 31, 1916.

[Drainage area, 49.5 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
1915.						
July	....	52	82.5	1.67	1.92	5,070
August	1,200	44	382	7.72	8.90	23,500
September	830	71	227	4.59	5.12	13,500
The period	....	....	....	....	....	42,100
1915-16.						
October	3,000	258	1,020	20.6	23.75	62,700
November	1,920	278	822	16.6	18.52	48,900
December	1,980	206	732	14.8	17.06	45,000
January	206	30	91.5	1.85	2.13	5,630
February	679	21	245	4.95	5.34	14,100
March	338	118	203	4.10	4.73	12,500
April	1,510	382	628	12.7	14.17	37,400
May	673	326	494	9.98	11.51	30,400
June	689	350	480	9.70	10.82	28,600
July	376	172	276	5.58	6.43	17,000
August	338	83	166	3.35	3.86	10,200
September	730	76	281	5.68	6.34	16,700
The year	3,000	21	453	9.15	124.66	329,000
1916.						
October	1,680	94	484	9.78	11.28	29,800
November	1,480	248	697	14.1	15.73	41,500
December	1,010	135	385	7.78	8.97	23,700
The period	....	....	....	....	....	95,000

MILL CREEK NEAR WRANGELL.

Location.—In latitude 56° 28′ N., longitude 132° 12′ W., near outlet of Lake Virginia on east shore of Eastern Passage, a narrow channel between Wrangell Island and mainland, 6 miles by water from Wrangell.

Drainage area.—50[1] square miles (measured on U. S. Coast and Geodetic Survey chart 8200).

Records available.—June 17, 1915, to December 31, 1916.

Gage.—Stevens water-stage recorder on left bank one-fourth mile below Lake Virginia and three-fourths mile above tidewater.

Discharge measurements.—Made from cable across creek, 10 feet upstream from gage.

Channel and control.—From the outlet of the lake, at an elevation of 100 feet above sea level and at a distance of 1 mile from tidewater, the creek descends in a series of rapids and falls. The bed is glacial drift and boulders at the rapids and rock outcrop at points of concentrated fall. The gage is in a pool of still water created by a small fall at a contracted point of channel. This fall makes a well-defined, permanent, and sensitive control.

Extremes of discharge.—Maximum stage recorded during period, 8 feet October 16, 1915 (discharge, computed from extension of rating curve, about 3,310 second-feet, differs from that published in Bulletin 642 because of revision of rating curve); minimum stage recorded, 0.02 foot February 11 (discharge, 15 second-feet).

Ice.—Ice forms on the lake, at gage, and along the banks, but the swift current and flow of relatively warm water from the lake keeps the control open.

Accuracy.—Stage-discharge relation permanent; not affected by ice. Rating curve well defined below 1,200 second-feet; extended above 1,200 second-feet. Operation of water-stage recorder satisfactory except for periods indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to the rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by averaging discharge for equal intervals of the day. Results good except for periods when water-stage recorder was not operating satisfactorily.

The drainage basin is covered with a heavy stand of timber to an elevation of 2,500 feet and a dense undergrowth of ferns, brush, alders, and devil's club, but because of the steep slopes and thin soil the run-off after heavy rains is rapid and the ground storage is small. During a dry, hot period in summer the flow is augmented by melting ice from glaciers at the headwaters of two of the tributary streams.

Discharge measurements of Mill Creek near Wrangell during the period June 17, 1915, to Dec. 31, 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
1915.		*Feet.*	*Sec.-ft.*	1916.		*Feet.*	*Sec.-ft.*
June 19	Canfield and Allen	2.54	477	Feb. 1[a]	G. H. Canfield	0.10	19
July 1	do	2.30	421	24	do	1.32	164
Nov. 3	G. H. Canfield	1.94	318	Sept. 21	do	4.01	1,060

[a] Ice at gage; control open.

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[1] Revised since last published.

Daily discharge, in second-feet, of Mill Creek near Wrangell for the period June 17, 1915, to Dec. 31, 1916.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1915.							
1	......	418	421	421	575	299	125
2	......	469	370	610	370	273	376
3	......	492	325	1,810	294	299	525
4	......	466	294	1,310	510	400	454
5	......	510	278	770	645	430	340
6	......	575	355	558	415	325	253
7	......	454	451	492	286	236	370
8	......	394	610	406	427	294	340
9	......	394	870	355	610	142	219
10	......	325	1,610	309	475	128	156
11	......	291	1,510	268	850	118	128
12	......	331	1,560	236	810	109	110
13	......	376	1,910	236	1,240	153	100
14	......	385	1,310	409	1,110	286	87
15	......	349	1,460	988	2,120	312	87
16	......	358	850	830	2,620	243	82
17	662	373	540	592	1,480	190	90
18	575	355	540	492	715	194	105
19	492	340	460	379	575	190	120
20	525	358	394	400	540	170	135
21	645	409	355	698	510	212	150
22	525	510	325	492	475	212	164
23	451	525	320	343	445	160	144
24	424	492	340	312	415	139	124
25	445	454	385	790	385	137	107
26	469	525	409	715	355	130	98
27	397	610	331	510	325	118	97
28	349	610	312	942	325	107	88
29	346	558	340	1,460	325	102	83
30	382	525	355	1,040	299	114	80
31	......	463	394	......	299	......	74

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1916.												
1	69	21	93	166	258	830	645	1,990	343	325	......	180
2	62	19	78	263	337	742	610	1,340	320	241	......	155
3	57	18	71	304	457	1,030	525	920	289	186	......	132
4	55	18	67	294	469	750	475	698	263	180	......	122
5	54	18	67	222	424	592	645	662	278	424	......	114
6	54	17	64	192	376	662	732	628	409	361	......	105
7	51	17	64	349	309	645	628	662	575	256	......	98
8	45	16	64	325	238	582	540	628	1,140	205	......	......
9	43	15	63	258	194	492	592	510	698	182	......	......
10	41	14	66	210	174	409	610	492	1,370	168	......	......
11	41	14	68	162	172	645	850	492	1,100	188	......	......
12	42	20	68	205	170	770	680	492	698	480	......	......
13	40	22	67	525	174	890	1,170	558	445	1,220	......	......
14	42	26	64	421	243	1,240	1,440	770	315	927	......	......
15	40	72	60	276	349	1,460	875	770	278	1,400	......	......
16	40	253	60	207	474	1,080	810	558	278	750	......	......
17	37	205	57	180	540	988	875	397	281	445	......	......
18	36	168	55	178	645	890	830	302	382	294	......	......
19	32	376	52	155	575	810	1,120	370	920	452	......	......
20	32	715	51	135	510	715	1,340	558	1,000	1,510	460	......
21	30	412	51	130	610	645	875	1,170	1,050	1,050	320	......
22	30	263	52	127	364	680	645	1,100	645	645	238	......
23	29	200	55	122	312	645	540	1,400	510	......	186	......
24	29	170	56	127	322	628	454	1,500	592	......	200	......
25	28	168	55	168	370	790	442	810	775	......	278	......
26	28	160	55	217	406	1,010	525	592	1,340	......	281	......
27	27	140	59	337	403	1,080	575	525	715	......	205	......
28	25	124	62	464	370	988	755	469	1,080	......	164	......
29	25	109	62	340	610	810	1,610	427	875	......	155	......
30	24	......	65	286	770	680	1,660	391	510	......	166	......
31	22	......	98	......	830	......	988	373	......	......	......	......

NOTE.—Water-stage recorder not working properly for following periods: Oct. 5 to Nov. 2, 1915; daily discharge estimated from maximum and minimum stages indicated by recorder, from climatic records and comparison with gage-height records for stations in adjacent drainage basins. Dec. 18–21, 1915; discharge interpolated. Oct. 1 to Nov. 20 and Dec. 8–31, 1916; discharge estimated from maximum and mimimum stages indicated by recorder and by comparison with record for Shelockum Lake outlet as follows: Oct. 23–31, 1,000 second-feet; Nov. 1–19, 253 second-feet; Dec. 8–31, 90 second-feet. Water frozen in well Jan. 23 to Feb. 11, 1916; discharge estimated from one discharge measurement and climatic records.

Monthly discharge of Mill Creek near Wrangell for the period June 17, 1915, to Dec. 31, 1916.

[Drainage area, 50 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
1915.						
June 17-30	662	346	478	9.56	4.98	13,300
July	610	291	442	8.84	10.19	27,200
August	1,910	278	645	12.9	14.87	39,700
September	1,780	236	639	12.8	14.28	38,000
The period						118,000
1915-16.						
October	2,620	286	672	13.4	15.45	41,300
November	430	102	207	4.14	4.62	12,300
December	525	74	175	3.50	4.04	10,800
January	69	22	39.0	.780	.90	2,400
February	715	14	131	2.62	2.83	7,540
March	98	51	63.5	1.27	1.46	3,900
April	525	122	245	4.90	5.47	14,600
May	830	170	402	8.04	9.27	24,700
June	1,460	409	806	16.1	17.96	48,000
July	1,660	442	808	16.2	18.68	49,700
August	1,990	302	728	14.6	16.83	44,800
September	1,370	263	649	13.0	14.50	38,600
The year	2,620	14	411	8.22	112.01	299,000
1916.						
October	1,510	168	674	13.5	15.56	41,400
November		[a] 89	248	4.96	5.53	14,800
December		[a] 52	98.9	1.98	2.28	6,080
The period						62,300

[a] Minimum stage recorded by the water-stage recorder, exact date not known.

GREEN LAKE OUTLET AT SILVER BAY, NEAR SITKA.

Location.—In latitude 56° 59′ N., longitude 135° 5′ W., at outlet of Green Lake, at head of Silver Bay, 10½ miles by water south of Sitka.

Drainage area.—Not measured.

Records available.—August 22, 1915, to December 31, 1916.

Gage.—Stevens water-stage recorder on right bank at outlet of lake, reached by trail which leaves the beach one-fourth mile north of mouth of stream, ascends a 600-foot ridge, and then drops down to the outlet of the lake.

Discharge measurements.—Made from cable across outlet 30 feet below gage.

Channel and control.—From Green Lake, 240 feet above sea level and 1,800 feet from tidewater, the stream descends in a series of falls and rapids through a narrow canyon whose exposed rock walls rise perpendicularly more than a hundred feet.

Extremes of discharge.—Maximum stage recorded during period, 10.22 feet at 5 a. m. September 19, 1916 (discharge, computed from extension of rating curve, 2,400 second-feet); minimum flow, estimated from hydrograph for Baranof Lake outlet and climatic records, 24 second-feet February 13.

Ice.—Ice forms on lake and at gage, but because of current and flow of relatively warm water from the lake the control remains open.

Accuracy.—Stage-discharge relation permanent. Rating curve well defined between 100 and 1,300 second-feet. Operation of water-stage recorder satisfactory except for periods indicated by breaks in record, as shown in the footnote to the daily-discharge table. Daily discharge for 1915 and February 15 to March 2 and November 1 to December 27, 1916, ascertained by applying to the rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table gage heights for regular intervals of day. Discharge April 3 to October 31, 1916, ascertained by use of discharge integrator.

In the fall and winter the flow is low because there is little ground storage and on most of the drainage area the precipitation is in the form of snow. This accumulated snow produces a large run-off during the spring, and the melting ice from the glacier and the ice-capped mountains augment the run-off from precipitation during the summer. The area of Green Lake is estimated to be only 100 acres.

Discharge measurements of Green Lake outlet at Silver Bay, near Sitka, during the period Aug. 22, 1915, to Dec. 31, 1916.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1915.	*Feet.*	*Sec.-ft.*	1916.	*Feet.*	*Sec.-ft.*	1916.	*Feet.*	*Sec.-ft.*
Aug. 22[a]	2.39	259	Feb. 16	0.47	96	Oct. 24	3.10	434
Nov. 22	1.18	136	June 7	2.66	346	24	4.22	630
Dec. 6	2.15	261	Oct. 24	2.92	397	25	6.61	1,210

[a] Tree lodged on control, causing backwater at gage.

Daily discharge, in second-feet, of Green Lake outlet at Silver Bay, near Sitka, for the period Aug. 22, 1915, to Dec. 31, 1916.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1915.						1915.					
1		278	620		83	16		942	717		70
2		943	380		130	17		577			73
3		765	368		224	18		438			89
4		451	593		281	19		365			107
5		315	1,070		210	20		537			163
6		257	515		239	21		510		226	126
7		246	299		278	22	262	443		148	115
8		228	359		173	23	278	236		126	116
9		208	413		120	24	293	242		114	98
10		184	337		97	25	325	890		104	80
11		173	895		84	26	383	1,310		97	75
12		169	848		75	27	315	782		88	77
13		326	1,090		69	28	374	734		80	74
14		913	1,040		68	29	448	1,380		78	77
15		1,400	1,180		68	30	470	1,010		80	65
						31	356				60

Daily discharge, in second-feet, of Green Lake outlet at Silver Bay, near Sitka, for the period Aug. 22, 1915, to Dec. 31, 1916—Continued.

Day.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1916.											
1		66	61	176	576	596	544	366	246	161	88
2		65	75	230	586	524	537	325	190	140	81
3			92	255	738	500	464	272	166	179	75
4			96	280	572	420	424	240	302	228	74
5			88	184	458	399	496	233	506	188	72
6			90	138	422	418	488	260	321	158	68
7			118	116	359	416	538	334	222	261	65
8			110	102	310	416	482	326	192	344	65
9			120	98	286	465	407	288	180	192	60
10			124	103	254	522	414	603	175	133	65
11			106	104	307	524	454	952	181	111	101
12			97	106	360	419	542	658	440	101	92
13			162	136	578	396	512	474	680	95	85
14	40		182	151	606	426	684	713	431	96	321
15	94		138	173	564	415	662	478	755	484	330
16	94		103	250	472	442	453	374	498	486	166
17	71		88	560	531	428	323	372	302	695	135
18	166		78	744	533	414	258	800	232	512	182
19	306		72	628	437	446	284	1,880	499	275	136
20	302		78	468	398	423	353	878	950	232	105
21	168		90	339	469	379	474	660	887	194	87
22	120		88	241	598	335	460	471	637	148	74
23	99		88	188	649	306	746	462	554	126	65
24	89		98	194	650	304	1,310	510	534	126	58
25	88		125	244	802	355	646	619	1,120	133	55
26	86		148	343	939	440	512	995	710	120	52
27	83		174	289	1,020	478	434	630	653	105	51
28	77		224	278	955	508	380	868	957	99	48
29	69	35	208	454	883	608	394	544	560	97	50
30		45	176	593	725	587	417	352	312	95	55
31		55		604		496	391		209		55

NOTE.—Discharge, Aug. 22-31, 1915, because of backwater caused by tree lodged on control, computed by applying recorded gage heights reduced by 0.25 foot to rating table. Because of clock stopping or water falling below well, discharge estimated, from climatic record at Sitka and from comparison of hydrograph for this station with that for Baranof Lake outlet, as follows: Oct. 17–31, 292 second-feet; Nov. 1–20, 1915, 281 second-feet; Jan. 1–31, 35 second-feet; Feb. 1–13, 24 second-feet; Feb. 14, 40 second-feet; Mar. 3–28, 1916, 45 second-feet.

Monthly discharge of Green Lake outlet at Silver Bay, near Sitka, for the period Aug. 22, 1915, to Dec. 31, 1916.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
1915.				
August 22-31	470	262	350	6,940
September	1,400	169	573	34,100
1915-16.				
October	1,180		487	29,900
November		78	188	11,200
December	281	60	118	7,260
January			35	2,150
February	306		78.1	4,490
March			46.3	2,850
April	224	61	117	6,960
May	744	98	283	17,400
June	1,020	254	568	33,800
July	608	304	445	27,400
August	1,310	258	499	30,700
September	1,880	233	564	33,600
The year	1,880		286	208,000
1916.				
October	1,120	166	471	29,000
November	695	95	210	12,500
December	330	48	97.3	5,980

BARANOF LAKE OUTLET AT BARANOF, BARANOF ISLAND.

Location.—In latitude 57° 5′ N., longitude 134° 54′ W., at townsite of Baranof, at head of Warm Spring Bay, east coast of Baranof Island, 18 miles east of Sitka across island, but 96 miles from Sitka by water through Peril Strait.

Drainage area.—Not measured.

Records available.—June 28, 1915, to December 31, 1916.

Gage.—Stevens water-stage recorder on right bank 700 feet below Baranof Lake and 800 feet above tidewater at head of Warm Spring Bay.

Discharge measurements.—Made from cable across stream 100 feet below lake and 600 feet above gage.

Channel and control.—From Baranof Lake, at elevation 130 feet above sea level, and 1,500 feet from tidewater, the stream descends in a series of rapids and small falls and enters the bay in a cascade of about 100 feet concentrated fall. The bed is of glacial drift, boulders, and rock outcrop. The gage is in an eddy 50 feet downstream from the foot of a small fall and 100 feet upstream from a riffle which forms a well-defined control.

Extremes of discharge.—Maximum stage recorded during period, 5.3 feet August 10, 1915 (discharge, computed from extension of rating curve, 3,350 second-feet); minimum flow estimated by discharge measurement and climatic data, 28 second-feet on February 13.

Ice.—Because of the swift current and flow of relatively warm water from the lake, the stream remains open.

Diversions.—The flume to Olsen's sawmill diverts from the stream 200 feet below gage only sufficient water to operate a 25-horsepower Pelton water wheel.

Accuracy.—Stage-discharge relation permanent, not affected by ice. Rating curve well defined below 2,000 second-feet. Operation of water-stage recorder satisfactory except for short periods indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging discharge for equal intervals of day. Results good except for periods when recorder did not operate satisfactorily, and for periods when water was frozen in well, for which they are fair.

The drainage area is rough and precipitous, and the vegetable and soil cover is thin, even on the foothills of the mountains. The run-off is rapid, and the ground storage is small. During a dry, hot period, however, the flow is greatly augmented by melting ice from several small glaciers and ice-capped mountains.

Discharge measurements of Baranof Lake outlet at Baranof during the period June 28, 1915, to Dec. 31, 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
1915.		*Feet.*	*Sec.-ft.*	1916.		*Feet.*	*Sec.-ft.*
June 28	Canfield and Drake	2.70	608	Feb. 13	G. H. Canfield	0.35	28.5
Sept. 4	Canfield and Peterson	2.78	621	May 23	do	2.24	389
27	Canfield and Gardner	3.12	833				
28	do	4.05	1,700				
Dec. 9	G. H. Canfield	1.79	255				

Daily discharge, in second-feet, of Baranof Lake outlet at Baranof for the period June 28, 1915, to Dec. 31, 1916.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1915.							
1	....	725	615	400	650	433	125
2	....	820	525	1,000	485	375	185
3	....	788	477	1,000	437	405	361
4	....	788	453	640	900	497	525
5	....	1,100	453	497	892	453	473
6	....	1,480	477	425	548	335	525
7	....	1,050	636	457	495	269	473
8	....	788	867	453	695	222	335
9	....	695	2,100	405	586	185	248
10	....	615	3,000	357	505	161	208
11	....	568	....	326	725	141	163
12	....	640	....	305	755	125	133
13	....	668	....	397	926	200	112
14	....	695	....	616	764	299	101
15	....	668	....	890	1,050	296	94
16	....	695	....	788	755	269	114
17	....	695	....	615	615	284	118
18	....	640	....	485	485	255	119
19	....	640	....	445	389	215	131
20	....	640	....	525	378	212	195
21	....	695	....	525	305	266	190
22	....	725	....	425	255	235	179
23	....	695	....	344	304	220	161
24	....	640	....	430	615	190	161
25	....	615	....	920	568	167	141
26	....	695	....	1,100	453	147	120
27	....	788	....	890	405	122	116
28	590	820	....	1,420	545	119	102
29	590	890	....	1,480	525	125	90
30	640	855	....	1,000	385	122	88
31	....	725	....	....	344	....	80

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1916.												
1	70	28	52	50	312	1,050	930	731	522	359	285	141
2	64	28	45	60	330	1,010	788	719	484	291	261	125
3	56	28	44	92	352	1,050	749	651	436	250	303	119
4	52	28	44	108	362	855	701	600	388	294	388	112
5	50	28	44	108	312	743	656	600	359	420	388	101
6	46	28	44	112	273	673	646	625	362	356	315	92
7	42	28	44	135	240	568	615	690	468	306	291	90
8	40	28	44	155	197	504	605	668	488	276	352	88
9	40	28	44	179	177	456	640	605	440	258	306	89
10	39	28	44	175	177	420	713	630	609	248	248	82
11	40	28	44	169	183	420	743	662	820	250	199	80
12	39	28	44	150	185	440	662	690	755	448	169	74
13	39	27	44	250	189	545	646	656	640	684	145	72
14	39	27	44	280	218	684	668	662	890	620	139	100
15	39	34	43	215	261	719	656	625	701	890	250	157
16	39	39	43	160	321	713	662	522	563	646	359	153
17	40	41	43	136	476	713	673	428	514	460	724	151
18	40	62	43	137	827	737	615	366	739	370	737	157
19	40	102	43	120	883	678	620	352	1,850	550	527	147
20	38	145	43	113	906	651	635	370	1,230	890	428	127
21	37	137	42	113	740	651	586	440	890	930	336	110
22	36	120	39	113	574	743	532	472	630	788	267	96
23	35	107	37	119	408	788	492	656	532	678	228	86
24	33	90	35	127	388	820	476	1,010	484	590	228	79
25	33	80	37	153	422	970	536	855	586	890	240	73
26	32	73	41	185	563	1,230	673	695	930	788	205	67
27	31	66	39	218	554	1,480	743	600	820	600	185	62
28	30	62	37	267	558	1,480	749	545	1,010	695	171	58
29	30	57	37	318	707	1,280	855	536	695	605	177	60
30	29	....	39	321	890	1,050	855	558	492	464	163	67
31	28	....	44	....	970	....	737	545	....	352	....	67

NOTE.—Discharge estimated for following periods, because of unsatisfactory operation of water-stage recorder: Aug. 11–13 (mean discharge, 886 second-feet), and Sept. 1–3, 1915, by comparison with records of flow for streams in adjacent drainage basins, and from minimum stage for period indicated by recording pencil; Jan. 20 to Feb. 13 from climatic records and discharge measurement of Feb. 13; Apr. 12–17 by comparison with record of flow for Green Lake outlet; May 21 and 22, 1916, interpolated.

Monthly discharge of Baranof Lake outlet at Baranof, for the period of July 1, 1915, to Dec. 31, 1916.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
1915.				
July	1,480	568	759	46,700
August	3,000	....	910	56,000
September	1,480	305	652	38,800
The period	....	....	....	142,000
1915–16.				
October	1,050	255	572	35,200
November	497	119	245	14,600
December	525	80	199	12,200
January	70	28	40.2	2,470
February	145	27	55.3	3,180
March	52	35	42.3	2,600
April	321	50	161	9,580
May	970	177	450	27,700
June	1,480	420	804	47,800
July	930	476	673	41,400
August	1,010	352	605	37,200
September	1,850	359	678	40,300
The year	1,850	27	378	274,000
1916.				
October	930	248	524	32,200
November	737	139	300	17,900
December	157	58	99.4	6,110
The period	....	....	....	56,200

SWEETHEART FALLS CREEK NEAR SNETTISHAM.

Location.—In latitude 57° 56½′ N., longitude 133° 41′ W., on east shore 1 mile from head of south arm of Port Snettisham, 3 miles south of mouth of Whiting River, 7 miles by water from Snettisham, and 42 miles by water from Juneau. No large tributaries enter river between gaging station and outlet of large lake, 2½ miles upstream.

Drainage area.—27 square miles (measured on the United States Geological Survey topographic map of the Juneau gold belt, edition of 1905).

Records available.—July 31, 1915, to December 31, 1916.

Gage.—Stevens water-stage recorder on right bank 300 feet upstream from tidewater on east shore of Port Snettisham.

Discharge measurements.—Made from cable across river one-fourth mile upstream from gage.

Channel and control.—From the outlet of lake at an elevation of 520 feet above sea level and 2½ miles from tidewater, the river descends in a series of rapids and falls through a narrow, deep canyon. Gage is in a pool at foot of two falls, each 25 feet high, which are known as Sweetheart Falls; outlet of pool is a natural rock weir, which forms a well-defined and permanent control for gage.

Extremes of discharge.—Maximum stage recorded during period, 4.2 feet August 14, 1915 (discharge, computed from an extension of the rating curve, 1,420[1] second-feet); minimum flow, estimated from discharge measurement and climatic data, 15 second-feet February 11.

Ice.—Stage-discharge relation not seriously affected by ice.

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[1] Differs from that published in Bulletin 642 because of a revision of rating curve.

Accuracy.—Stage-discharge relation practically permanent; affected by ice January 19 to February 22. Rating curve well defined between 80 and 1,300 second-feet; extended beyond these limits by estimation. Operation of water-stage recorder satisfactory except for periods indicated by breaks in record, as shown in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or for days of considerable fluctuation by averaging results obtained by applying to rating table gage heights for regular intervals of day. Results excellent except for periods of break in record and for stages below 80 and above 1,300 second-feet, for which they are fair.

In the fall and winter the run-off is small because the precipitation is in the form of snow and because of the small amount of ground storage; during a hot, dry period the low run-off from the ground and lake storage is augmented by melting ice from one glacier.

Discharge measurements of Sweetheart Falls Creek near Snettisham during period July 31, 1915, to Dec. 31, 1916.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1915.	*Feet.*	*Sec.-ft.*	1916.	*Feet.*	*Sec.-ft.*	1916.	*Feet.*	*Sec.-ft.*
July 31	1.95	520	Feb. 5	[a]0.33	17.8	Oct. 14	3.20	996
Aug. 29	1.49	329	June 21	2.22	564	Nov. 12	.72	112
Nov. 13	1.07	195	Oct. 13	3.82	1,240			
Dec. 14	.53	82						

[a] Stage-discharge relation affected by ice.

Daily discharge, in second-feet, of Sweetheart Falls Creek near Snettisham for the period Aug. 1, 1915, to Dec. 31, 1916.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1915.						1915.					
1	453	298	700	180	105	16	1,070	554	902	205	82
2	396	542	504	188	140	17	740	550	700	170	87
3	352	840	406	234	145	18	562	478	504	165	99
4	335	780	534	280	136	19	456	482	386	140	105
5	328	589	573	260	124	20	386	632	316	130	97
6	328	467	442	240	134	21	346	760	257	143	99
7	324	396	369	220	161	22	316	593	211	138	108
8	316	335	346	200	132	23	291	449	180	124	116
9	335	284	284	180	106	24	284	431	158	114	99
10	431	247	324	160	87	25	346	600	147	105	86
11	497	222	493	140	92	26	403	700	147	101	82
12	780	202	558	130	87	27	372	600	151	97	90
13	1,220	194	628	188	82	28	346	760	163	94	79
14	1,330	247	772	270	81	29	335	1,090	194	87	69
15	1,220	414	1,070	247	82	30	328	986	180	99	70
						31	305	....	158	....	65

Daily discharge, in second-feet, of Sweetheart Falls Creek near Snettisham for the period Aug. 1, 1915, to Dec. 31, 1916—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1916.												
1	55	22	36	......	306	840	760	......	322	438	277	103
2	50	21	37	......	355	902	680	......	316	342	230	98
3	48	21	36	......	442	1,030	585	......	296	277	197	94
4	48	19	39	......	467	910	534	......	283	303	160	100
5	49	19	37	......	386	760	486	......	316	467	152	108
6	47	18	36	......	319	752	463	......	362	410	150	98
7	43	18	36	......	270	640	438	......	346	336	178	94
8	42	18	36	......	224	542	435	......	379	286	209	90
9	45	18	36	......	203	467	449	......	355	255	181	83
10	47	18	37	......	192	424	463	......	815	233	148	86
11	47	18	37	......	189	463	478	......	952	325	124	88
12	45	18	38	......	192	512	467	......	760	960	112	86
13	46	18	39	168	200	684	456	......	808	1,220	100	80
14	43	......	39	181	215	944	442	......	760	1,060	103	105
15	42	......	39	170	252	1,120	431	......	640	1,200	224	132
16	39	......	39	146	303	1,010	438	......	512	944	255	128
17	38	......	40	128	362	989	460	......	445	652	329	105
18	38	......	40	114	396	808	497	......	616	489	369	139
19	36	......	41	105	435	688	......	......	1,090	700	316	135
20	34	......	42	100	456	620	......	......	1,040	1,190	306	118
21	31	......	43	100	453	597	......	......	936	993	270	105
22	30	......	44	102	417	640	......	......	724	696	230	98
23	29	56	45	103	379	696	......	......	740	620	200	88
24	29	54	......	120	362	740	......	......	672	546	189	88
25	29	47	......	137	372	832	......	......	732	776	175	68
26	29	36	......	155	403	973	......	680	860	804	155	48
27	28	29	......	195	408	1,070	......	562	736	644	130	27
28	26	29	......	245	417	1,070	......	493	898	700	118	33
29	25	32	......	283	546	1,020	......	456	792	589	112	32
30	25	......	......	299	700	881	......	400	577	442	112	31
31	23	......	......	......	788	......	......	365	......	342	......	36

NOTE.—Because of clock stopping or backwater from ice, discharge estimated from climatic record at Juneau and from comparison of hydrograph for this station with those for Long River and Mill Creek: Nov. 5-11, 1915, Jan. 19 to Feb. 13 and Mar. 18-22, Dec. 25, 26, and 29, 1916, daily discharge; Feb. 14-22, 64 second-feet; Mar. 24-31, 55 second-feet; Apr. 1-12, 152 second-feet; July 19-31, 505 second-feet; and Aug. 1-25, 1916, 604 second-feet. Discharge, Aug. 1 to Oct 19, 1915, above 335 second-feet, differs from that published in Bulletin 642, because of a revision of the rating curve, based on highwater measurements obtained in 1916.

Monthly discharge of Sweetheart Falls Creek near Snettisham for the period Aug. 1, 1915, to Dec. 31, 1916.

[Drainage area, 27 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
1915.						
August	1,330	284	501	18.6	21.44	30,800
September	1,090	194	524	19.4	21.64	31,200
1915-16.						
October	1,070	147	412	15.3	17.64	25,300
November	280	87	168	6.22	6.94	10,000
December	161	65	101	3.74	4.31	6,210
January	55	23	38.3	1.42	1.64	2,360
February	....	18	38.1	1.41	1.52	2,190
March	....	....	43.0	1.59	1.83	2,640
April	....	....	156	5.78	6.45	9,280
May	788	189	368	13.6	15.68	22,600
June	1,120	424	787	29.1	32.47	46,800
July	....	....	501	18.6	21.44	30,800
August	[a]1,180	....	582	21.6	24.90	35,800
September	1,090	288	636	23.6	26.33	37,800
The year	1,120	18	319	11.8	161.15	232,000
1916.						
October	1,220	233	621	23.0	26.52	38,200
November	369	100	194	7.19	8.02	11,500
December	139	27	87.7	3.25	3.75	5,390
The period	....	....	....	....	....	55,100

[a] Maximum stage indicated by water-stage recorder; exact date not known.

CRATER LAKE OUTLET AT SPEEL RIVER, PORT SNETTISHAM.

Location.—At outlet of Crater Lake, 1 mile upstream from the edge of tide flats at head of north arm of Port Snettisham, 2 miles by trail from cabins of Speel River Project (Inc.), which are 42 miles by water from Juneau.

Drainage area.—11.9 square miles (measured on topographic maps of the Alaska Boundary Tribunal, edition of 1895).

Records available.—January 23, 1913, to December 31, 1916.

Gage.—Stevens water-stage recorder on left shore of lake, 100 feet upstream from outlet. A locally-made water-stage recorder having a natural vertical scale and a time scale of 1 inch to 24 hours was used until replaced by Stevens gage June 29, 1916. The gage datum remained the same during the period. During the winter months, because of inaccessible location and deep snow, the operation of the gage at the lake was discontinued, and the stage read at staff gage in channel exposed at low tide at beach. The first gage at beach was set at an unknown datum and washed out in winter of 1915–1916. Another staff gage was set at about the same location and used after November 24, 1916.

Discharge measurements.—Made from cable across outlet of lake, 100 feet downstream from gage and 10 feet upstream from crest of first falls. The rope sling from which discharge measurements were first made was replaced in fall of 1915 by a standard United States Geological Survey gaging car, making more accurate measurements possible.

Channel and control.—The gage is on left shore of lake, 100 feet upstream from outlet where the stream becomes constricted into a narrow channel, the bed of which is composed of large boulders and rock outcrop, which form a well-defined and permanent control.

Extremes of discharge.—Maximum stage during the period, 5.9 feet, August 13, 1915 (discharge, estimated from extension of rating curve, 1,680 second-feet); minimum flow, 5 second-feet, February 1 to 13, 1916, estimated from one discharge measurement and climatic records.

Accuracy.—Stage-discharge relation permanent. Rating curve defined by 19 discharge measurements, 13 of which were made by employees of the Speel River Project (Inc.) and 6 by an engineer of the United States Geological Survey, and is well defined below and extended above 1,000 second-feet. Rating curve used November 24 to December 31, 1916, for staff gage at beach, fairly well defined. Operation of water-stage recorder used during 1914 and 1915 not satisfactory because of slippage of float cord and unfavorable time and gage-height scales. Errors from these sources probably compensating in computation of monthly mean discharge. Operation of Stevens water-stage recorder satisfactory except September 1 to 28, 1916, when it stopped. Daily discharge for 1913, except as indicated in note to daily-discharge table, is the result of discharge measurements made nearly every day by float or current meter and was furnished by the Speel River Project (Inc.). Discharge record January 1 to May 2, December 1 to 31, 1914, and January 1 to April 20, 1915, computed from gage-height records for staff gage at beach and furnished by the Speel River Project (Inc.). Daily discharge May 3 to November 30, 1914, and April 21 to November 25, 1915, ascertained by engineers of the United States Geological Survey by applying to rating table mean daily gage heights furnished by Speel River Project (Inc.). Daily discharge July to November, 1916, ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, and December 9 to 23, 1916, from occasional readings of staff gage at beach. Results good for records obtained from gage at lake; other records probably fair.

Crater Lake is at an elevation of 1,010 feet above sea level and covers 1.1 square miles. The sides of the mountains surrounding the lake are steep and barren and the tops are covered by glaciers.

Discharge measurements of Crater Lake outlet at Speel River during the period Oct. 13, 1914, to Dec. 31, 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
1914.		*Feet.*	*Sec.-ft.*	1916.		*Feet.*	*Sec.-ft.*
Oct. 13	Kennedy and Lindsay.	1.7	235	Feb. 4	G. H. Canfield.........	([a])	5.0
15	Mark Rascovich........	3.17	614	May 10	.....do.................	[b] 0.47	50.6
27	Kennedy and Lindsay.	1.45	179	June 29	.....do.................	3.22	616
29	Kennedy and Peterson.	2.52	376	July 1	.....do.................	2.58	448
30	Kennedy and Lindsay.	2.05	276	30	Gust Grosseth..........	3.98	878
Nov. 19	Lindsay and Peterson..	1.58	205	Aug. 11	.....do.................	2.19	325
				31	G. H. Canfield.........	2.22	344
1915.				Oct. 17	.....do.................	1.59	199
May 21	R. L. Lindsay..........	1.87	241	Nov. 17	.....do.................	.60	73
June 21	Gust Grosseth..........	2.30	344	Dec. 12	Gust Grosseth..........	[a] 1.19	33
23	R. L. Lindsay..........	2.20	294	16	.....do.................	.10	37.6
Aug. 3	G. H. Canfield.........	2.49	397				
11	....	3.16	586				

[a] Measurement made at tidewater flats.
[b] Gage height referred to temporary gage; datum unknown.

Daily discharge, in second-feet, of Crater Lake outlet at Speel River for the period Jan. 23, 1913, to Dec. 31, 1916.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1913.												
1	......	[a] 55	30	36	66	648	732	528	741	405	108	41
2	......	50	35	79	58	533	......	528	[a] 600	[a] 350	134	47
3	......	[a] 42	35	67	58	389	......	528	[a] 500	291	123	76
4	......	33	44	70	53	394	......	689	445	231	108	[a] 65
5	......	[a] 49	68	56	51	410	......	1,100	396	[a] 220	98	55
6	......	[a] 65	88	45	52	395	......	1,100	396	206	[a] 98	41
7	......	81	77	[a] 40	53	385	......	1,220	463	[a] 180	98	41
8	......	[a] 60	94	36	58	542	770	1,120	[a] 460	162	134	61
9	......	44	94	41	66	395	770	1,100	[a] 460	128	134	61
10	......	31	88	41	78	400	794	1,100	463	[a] 110	[a] 140	61
11	......	[a] 29	[a] 76	41	94	424	794	924	567	99	146	53
12	......	28	64	45	108	395	794	871	666	[a] 90	[a] 146	55
13	......	40	59	77	160	377	823	773	666	[a] 80	146	38
14	......	43	45	77	172	377	[a] 840	773	726	71	[a] 160	31
15	......	85	56	81	211	[a] 400	[a] 860	689	726	77	[a] 180	31
16	......	78	53	69	160	[a] 500	888	689	580	182	[a] 200	31
17	......	69	45	56	160	528	888	594	523	99	[a] 170	30
18	......	75	39	78	210	528	1,100	594	352	99	[a] 140	[a] 28
19	......	48	36	64	293	528	1,100	594	231	[a] 750	[a] 110	[a] 25
20	......	46	34	61	270	586	1,100	570	249	1,400	86	23
21	......	49	32	53	270	625	990	542	523	774	[a] 80	21
22	......	37	29	64	293	625	888	542	[a] 600	[a] 650	79	39
23	34	36	29	66	354	625	858	542	[a] 500	519	[a] 80	17
24	......	33	26	64	354	625	752	990	[a] 450	387	[a] 70	18
25	......	32	[a] 26	56	343	625	689	1,070	396	123	[a] 60	18
26	......	28	27	53	343	625	......	1,100	315	77	[a] 50	18
27	66	23	34	50	354	752	......	1,330	196	[a] 66	[a] 40	18
28	......	28	39	50	354	752	......	1,390	449	54	36	16
29	71	......	[a] 36	50	400	794	......	1,110	[a] 500	[a] 44	39	43
30	......	......	34	53	400	752	......	1,010	580	35	38	43
31	......	......	24	......	400	......	......	880	......	108	......	38

[a] Estimated.

Daily discharge, in second-feet, of Crater Lake outlet at Speel River for the period Jan. 23, 1913, to Dec. 31, 1916—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1914.												
1	32	13	27	21	280	178	429	350	429	429	253	70
2	27	13	27	18	180	130	429	350	429	594	219	50
3	27	13	27	17	94	94	594	429	350	692	153	32
4	27	13	45	18	94	94	429	429	350	517	124	27
5	26	13	35	21	94	94	429	429	293	429	100	24
6	26	13	40	22	94	130	350	429	293	429	85	23
7	26	12	35	22	94	178	350	429	293	429	76	22
8	26	16	32	26	94	178	350	350	293	429	82	22
9	26	14	30	32	130	178	429	350	350	......	126	22
10	26	16	26	40	130	221	429	350	692	......	113	22
11	26	16	32	50	130	233	429	293	350	......	98	21
12	27	16	32	83	112	241	594	293	350	......	88	21
13	27	16	35	80	94	293	594	293	221	221	81	18
14	35	27	43	113	94	293	815	293	130	692	75	16
15	42	333	43	98	130	350	815	293	94	692	61	10
16	32	118	45	80	130	350	692	221	94	350	48	13
17	24	80	37	77	112	350	594	293	94	221	52	16
18	22	118	40	65	94	350	594	350	94	293	104	16
19	21	55	62	65	130	293	594	429	261	178	174	10
20	20	45	55	58	178	221	429	429	241	221	159	10
21	16	45	53	52	178	221	594	350	94	153	131	21
22	16	45	45	60	178	293	594	350	94	94	98	21
23	16	35	45	57	221	350	594	350	178	94	92	45
24	6	35	43	53	221	350	815	429	293	261	82	40
25	6	40	37	50	221	350	815	429	350	261	78	35
26	6	35	35	45	178	429	429	429	350	94	78	27
27	6	34	32	55	178	429	350	594	293	178	73	24
28	6	30	27	60	130	429	350	815	221	221	71	18
29	6	......	27	65	130	429	350	815	221	350	67	16
30	10	......	24	80	178	429	350	594	178	293	64	16
31	10	......	22	......	178	......	429	429	......	293	......	13

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1915.											
1	18	18	32	47	49	203	472	429	362	241	52
2	21	16	32	47	64	219	457	402	762	233	59
3	38	16	32	48	73	282	443	402	658	174	161
4	42	13	33	53	82	350	429	402	626	274	114
5	45	10	38	57	103	350	429	416	626	304	49
6	55	10	38	62	114	416	402	402	626	227	45
7	53	10	40	65	139	362	327	388	388	136	45
8	53	10	42	67	161	316	282	375	221	113	45
9	55	42	42	67	186	293	282	429	223	89	40
10	53	42	45	72	212	338	350	517	200	112	37
11	48	16	45	72	261	375	457	728	178	241	34
12	45	16	45	77	327	443	472	1,190	164	350	32
13	38	18	42	78	327	487	472	1,680	159	176	34
14	38	18	40	90	327	532	457	868	205	327	46
15	40	16	38	104	327	658	472	532	304	487	42
16	45	16	40	112	327	710	472	487	388	832	42
17	55	10	45	120	327	562	487	375	388	375	36
18	45	10	48	120	327	502	487	282	338	183	31
19	42	12	48	104	327	457	517	272	375	153	34
20	38	10	48	78	316	443	578	272	443	104	36
21	33	10	58	79	274	416	578	278	517	92	38
22	32	12	62	78	257	416	578	274	443	75	32
23	32	13	62	75	267	388	547	274	261	58	34
24	27	16	57	73	282	416	517	282	241	51	34
25	24	18	45	70	280	429	547	338	562	43	35
26	21	24	53	68	280	416	578	429	642	41	......
27	18	27	53	65	280	350	658	517	443	37	......
28	18	32	48	61	280	375	762	402	402	39	......
29	16	......	48	58	263	443	762	327	282	60	......
30	16	......	45	52	233	472	642	293	251	58	......
31	16	......	45	......	216	......	487	278	......	58	......

Daily discharge, in second-feet, of Crater Lake outlet at Speel River for the period Jan. 23, 1913, to Dec. 31, 1916—Continued.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1916.							1916.						
1	429	457	....	124	....	....	16	316	362	....	338	53	39
2	388	375	....	108	....	....	17	362	265	....	214	78	42
3	327	327	....	108	....	....	18	402	221	....	152	101	46
4	316	304	....	150	....	....	19	388	338	....	265	83	41
5	316	362	....	253	....	....	20	338	675	....	517	78	36
6	282	388	....	178	....	....	21	327	885	....	304	68	33
7	276	429	....	139	....	....	22	276	692	....	251	58	29
8	282	375	....	121	....	....	23	245	547	....	208	50	26
9	293	316	....	120	....	29	24	231	780	....	166	....	.....
10	316	304	....	146	34	36	25	263	594	....	293	....	.....
11	338	338	....	338	32	42	26	338	457	....	316	....	.....
12	338	517	....	990	35	34	27	375	416	....	208	....	.....
13	316	728	....	762	38	35	28	532	416	443	193	....	.....
14	293	868	....	472	38	36	29	850	388	267	156	....	.....
15	304	562	....	547	41	38	30	850	362	174	119	....	.....
							31	578	338	....	111	....	.....

NOTE.—Discharge estimated by comparison with records of flow for streams in adjacent drainage basins as follows: July 2–7, 750 second-feet; July 26–31, 1913, 800 second-feet; Oct. 9–12, 1914, 150 second-feet; and Nov. 26–30, 1915, 32 second-feet. No gage-height record available Nov. 26, 1915, to June 30, 1916.

Monthly discharge of Crater Lake outlet at Speel River for the periods Feb. 1, 1913, to Nov. 30, 1915, and July 1 to Dec. 31, 1916.

[Drainage area, 11.9 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
1913.						
February	85	23	47.0	3.95	4.11	2,610
March	94	24	48.3	4.06	4.68	2,970
April	81	36	57.3	4.82	5.38	3,410
May	400	51	203	17.1	19.71	12,500
June	794	377	531	44.6	49.76	31,600
July	1,100	....	830	69.7	80.36	51,000
August	1,390	528	858	72.1	83.12	52,800
September	741	196	491	41.3	46.08	29,200
The period	....	....	....	....	....	186,000
1913–14.						
October	1,400	35	260	21.8	25.13	16,000
November	200	36	108	9.08	10.13	6,430
December	76	16	38.2	3.21	3.70	2,350
January	42	6	20.9	1.76	2.03	1,290
February	333	12	45.0	3.78	3.94	2,500
March	62	22	36.7	3.08	3.55	2,260
April	113	17	52.8	4.44	4.95	3,140
May	280	94	144	12.1	13.95	8,850
June	429	94	272	22.9	25.55	16,200
July	815	350	517	43.4	50.04	31,800
August	815	221	409	34.4	39.66	25,100
September	692	94	266	22.4	24.99	15,800
The year	1,400	6	182	15.3	207.62	132,000
1914–15.						
October	692	94	313	26.3	30.32	19,200
November	255	48	104	8.74	9.75	6,190
December	70	10	28.9	2.01	2.32	1,470
January	55	16	36.1	3.03	3.49	2,220
February	42	10	17.2	1.45	1.51	955
March	62	32	44.6	3.75	4.32	2,740
April	120	47	74.0	6.22	6.94	4,400
May	327	49	235	19.7	22.71	14,400
June	710	203	414	34.8	38.83	24,600
July	762	282	497	41.8	48.19	30,600
August	1,680	272	469	39.4	45.42	28,800
September	762	159	389	32.7	36.48	23,100
The year	1,680	10	219	18.4	250.28	159,000

Monthly discharge of Crater Lake outlet at Speel River for the period Feb. 1, 1913, to Nov. 30, 1915, and July 1, to Dec. 31, 1916—Continued.

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
1915.						
October	832	37	185	15.5	17.87	11,400
November	161	....	44.9	3.77	4.21	2,670
1916.						
July	850	231	370	31.1	35.85	22,800
August	885	221	464	39.0	44.96	28,500
September	....	....	470	39.5	44.07	28,000
October	990	108	270	22.7	26.17	16,600
November	101	....	51.2	4.30	4.80	3,050
December	46	....	32.7	2.75	3.17	2,010

LONG LAKE OUTLET NEAR PORT SNETTISHAM.

Location.—At outlet of Long Lake, 5 miles upstream from mouth of Long River; 2 miles by trail and water across Second Lake from cabins of the Speel River Project (Inc.), which are at head of north arm of Port Snettisham and 42 miles by water from Juneau.

Drainage area.—31.9 square miles (measured on topographic maps of the Alaska Boundary Tribunal, edition of 1895).

Records available.—January 23, 1913, to November 10, 1915.

Gage.—Lietz 7-day graph, water-stage recorder on left shore in still water of lake 30 feet upstream from crest of falls in left channel of outlet. Vertical movement of float in a tank set at lake edge transmitted, by system of pulleys and counterpoise, to gage in house 15 feet back from bank.

Discharge measurements.—At all stages made, with meter on rod, from log footbridge across left channel and suspension footbridge across right channel. Measuring section poor because of rough bed, swift current, and large angle which direction of current makes with measuring section.

Channel and control.—The outlet from lake consists of two narrow channels separated by a small island. The bed, which consists of rock ledge and large boulders at measuring section about 30 feet below gage, breaks off abruptly into high falls. Control permanent.

Extremes of discharge.—Maximum discharge during the periods of records, 4,250 second-feet, October 20, 1913; minimum flow, 32 second-feet, several days in January and February, 1914.

Ice.—Stage-discharge relation not affected by ice.

Accuracy.—Stage-discharge relation permanent. Rating curve defined by 9 discharge measurements, 5 of which were made in 1914 by employees of the Speel River Project (Inc.), and 4 in 1915 and 1916 by an engineer of the United States Geological Survey, and is fairly well defined between 30 and 1,800 second-feet.

The gage was operated, daily gage heights determined and furnished by the Speel River Project (Inc.). Daily discharge was ascertained by applying gage heights to rating table. Results fair except below 150 second-feet and above 1,500 second-feet, for which they are poor. Because gage could not be operated during the winter and because satisfactory measurements of discharge could not be made at high stages, this gaging station was replaced by another one installed on Long River below outlet of Second Lake on November 11, 1915.

Long Lake is 808 feet above sea level and covers 3.1 square miles. The sides of mountains surrounding lake are steep and barren, and the tops are covered with glaciers.

Discharge measurements of Long Lake outlet at Port Snettisham, during the period Jan. 30, 1914, to Dec. 31, 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
1914.		*Feet.*	*Sec.-ft.*	1915.		*Feet.*	*Sec.-ft.*
Jan. 30	Gust Grosseth	−0.70	31.4	Aug. 4	G. H. Canfield	2.82	981
May 29	do	1.41	416				
	Lass and Peterson	1.22	363	1916.			
Oct. 14	Lindsay and Kennedy.	3.00	1,160	June 30	do	3.22	1,080
19	Kennedy and Grosseth.	2.75	990	July 15	do	2.38	696
				Nov. 16	do	.35	141

NOTE.—Results of measurements in 1914 furnished by Speel River Project (Inc.), Juneau.

Daily discharge, in second-feet, of Long Lake outlet at Port Snettisham, for the period Jan. 23, 1913, to Nov. 10, 1915.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1913.												
1		[a]110	102	98	144	737	1,830	1,830	1,770	2,090	546	201
2		117	116	[a]100	149	738		1,370	968	1,370	582	188
3			[a]120	88	149	660		1,370	[a]840	[a]1,000	654	172
4			138	[a]100	112	596		1,770	717	764	588	314
5			189	105	161	624		2,080	[a]600	643	[a]460	294
6			[a]250	98	112	612		2,620	[a]700	492	330	250
7			235	85	108	660		2,770	814	[a]400	[a]500	220
8			[a]290	85	154	636		2,090	[a]800	302	919	282
9		88	297	[a]88	135	579	1,340	2,090	[a]800	[a]300	[a]700	306
10		[a]76	[a]260	90	149	817	1,340	1,770	884	295	[a]500	352
11		71	224	86	144	817	1,370	1,640	1,160	[a]250	[a]400	286
12		72	196	86	219	817	1,370	1,340	1,370	210	340	306
13		70	188	[a]100	202	908	1,500	1,210	1,770	[a]220	340	154
14		142	176	112	375	869	[a]2,000	1,210	2,190	228	421	146
15		203	151	171	411	[a]900	[a]2,400	1,080	2,410	[a]226	615	146
16		113	142	141	426	[a]1,000	2,620	1,080	2,140	223	518	109
17		128	134	171	451	1,000	2,620	1,080	1,670	228	361	124
18		128	125	176	500	1,160	2,740	1,000	1,360	223	382	[a]114
19		210	[a]110	185	510	1,550	2,740	1,000	1,180	[a]2,000	311	105
20		174	97	184	510	1,550	2,740	1,000	1,410	4,250	258	96
21		128	[a]90	171	512	1,530	2,500	1,000	[a]1,500	[a]3,600	188	84
22		104	83	171	539	1,600	2,280	[a]1,000	1,770	[a]3,200	167	84
23	130	104	78	171	556	1,600	2,080	[a]1,000	[a]1,450	2,870	155	80
24		100	[a]76	161	556	1,600	1,890	1,770	[a]1,100	1,850	159	76
25		100	75	161	880	1,640	1,830	2,280	814	1,930	146	69
26	90	100	78	159	880	1,600	1,830	2,620	717	1,610	[a]140	62
27	102	96	[a]83	149	909	1,770	1,870	2,870	644	1,360	139	63
28	187	96	88	144	974	1,770	1,640	3,170	884	[a]1,200	159	105
29	96		85	144	1,000	1,770	1,830	2,670	[a]1,500	1,000	146	99
30			82	144	[a]1,000	1,640	2,010	2,620	2,080	550	134	80
31			[a]80		1,000		1,890	2,190		919		73

[a] Estimated.

Daily discharge, in second-feet, of Long Lake outlet at Port Snettisham, for the period Jan. 23, 1913, to Nov. 10, 1915—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1914.												
1	58	32	89	62	240	413	1,140	1,040	1,190	384	630	125
2	62	32	89	58	289	413	1,290	940	990	384	556	137
3	54	34	37	58	315	398	1,090	890	844	356	458	137
4	58	34	50	58	342	370	940	940	754	342	398	137
5	58	32	50	58	289	342	754	1,190	798	592	328	137
6	54	32	89	46	289	315	712	1,190	844	798	276	132
7	58	34	89	50	289	370	712	1,090	844	611	228	126
8	58	37	77	50	264	413	630	890	754	458	228	126
9	58	37	77	50	289	490	670	844	754	398	315	126
10	54	37	77	58	315	506	940	798	1,040	398	302	126
11	58	32	69	71	315	556	1,290	798	1,090	413	264	122
12	54	32	77	116	342	592	1,290	754	754	398	228	122
13	52	32	77	132	328	798	1,410	712	630	522	194	103
14	65	32	65	160	315	940	1,950	670	556	990	171	92
15	62	50	67	171	342	940	1,650	670	490	1,290	171	56
16	56	240	75	160	342	940	1,470	670	428	1,040	171	74
17	52	132	102	171	328	990	1,410	844	398	754	217	92
18	52	124	102	160	315	1,040	1,470	1,090	342	630	302	92
19	52	116	124	160	342	940	1,240	1,090	289	522	398	56
20	50	102	116	160	370	754	1,040	1,090	276	458	398	56
21	50	102	109	141	370	754	1,530	990	328	413	342	122
22	50	89	116	132	370	940	1,470	890	384	342	289	122
23	50	89	116	132	370	940	1,650	798	384	276	264	257
24	32	77	109	132	384	890	1,950	940	328	264	206	228
25	32	77	102	124	370	940	1,710	1,190	670	289	171	200
26	37	77	89	116	370	940	1,290	1,290	844	428	150	152
27	37	77	83	116	384	990	1,090	1,590	630	490	141	137
28	37	77	67	132	384	940	940	1,830	458	522	132	103
29	32	......	67	132	398	940	890	2,220	384	844	132	99
30	32	......	58	171	398	940	844	1,650	384	844	132	92
31	37	......	67	......	413	......	940	1,350	......	712	......	74

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1915.								
1	......	132	556	990	1,350	844	1,140	141
2	......	132	556	1,040	1,190	1,530	754	160
3	......	141	592	1,040	1,090	1,830	592	217
4	......	182	754	1,040	940	1,350	940	264
5	......	252	754	990	940	1,040	940	252
6	......	342	844	990	940	844	670	217
7	......	398	890	890	890	712	522	194
8	......	428	798	798	890	670	428	150
9	......	428	754	754	890	630	342	141
10	......	428	754	712	1,090	556	342	96
11	......	428	798	798	1,470	522	490	......
12	......	458	890	890	2,080	490	630	......
13	......	522	940	990	3,050	490	556	......
14	......	592	990	990	3,210	592	670	......
15	......	670	1,040	1,040	2,650	754	1,350	......
16	......	712	1,190	1,040	2,150	890	1,140	......
17	......	712	1,190	1,040	1,710	844	890	......
18	428	754	890	1,040	1,240	712	630	......
19	370	712	940	1,040	890	798	458	......
20	315	670	890	1,090	798	1,140	370	......
21	264	670	844	1,190	754	1,470	302	......
22	228	630	798	1,240	754	1,190	252	......
23	206	670	798	1,140	712	592	182	......
24	194	712	798	1,090	754	844	160	......
25	194	670	798	1,090	940	1,290	141	......
26	194	670	844	1,290	1,140	1,470	132	......
27	182	712	798	1,410	990	1,140	132	......
28	171	670	798	1,530	940	1,290	132	......
29	150	670	844	1,650	890	1,950	150	......
30	141	630	890	1,650	844	1,590	150	......
31	......	592	......	1,530	754	......	141	......

NOTE.—Mean discharge estimated as follows: Feb. 3–8, 1913, 140 second-feet; July 2–8, 1913, 1,500 second-feet.

Monthly discharge of Long Lake outlet at Port Snettisham, for the period Feb. 1, 1913, to Nov. 10, 1915.

[Drainage area, 31.9 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
1913.						
February	....	70	120	3.76	3.92	6,660
March	297	75	148	4.48	5.16	8,790
April	185	85	131	4.11	4.59	7,800
May	1,000	108	449	14.1	16.26	27,600
June	1,770	579	1,120	35.1	39.16	66,600
July	2,740	....	1,900	59.6	68.71	117,000
August	3,170	1,000	1,760	55.2	63.64	108,000
September	2,410	600	1,270	39.8	44.40	75,600
The period	....	....	....	....	....	418,000
1913–14.						
October	4,250	210	1,150	36.1	41.62	70,700
November	919	134	375	11.8	13.17	22,300
December	352	62	163	5.11	5.89	10,000
January	65	32	50.0	1.57	1.81	3,070
February	240	32	67.8	2.13	2.22	3,770
March	124	37	83.3	2.61	3.01	5,120
April	171	46	111	3.48	3.88	6,600
May	413	240	338	10.6	12.22	20,800
June	1,040	315	724	22.7	25.33	43,100
July	1,950	630	1,210	37.9	43.69	74,400
August	2,220	670	1,060	33.2	38.28	65,200
September	1,190	276	629	19.7	21.98	37,400
The year	4,250	32	501	15.7	213.10	362,000
1914–15.						
October	1,290	264	554	17.4	20.06	34,100
November	630	132	273	8.56	9.55	16,200
December	257	56	121	3.79	4.37	7,440
April 18–30	428	141	234	7.34	3.55	6,030
May	754	132	529	16.6	19.14	32,500
June	1,190	556	841	26.4	29.45	50,000
July	1,650	712	1,100	34.5	39.77	67,600
August	3,210	712	1,260	39.5	45.54	77,500
September	1,950	490	1,000	31.3	34.92	59,500
1915.						
October	1,350	132	507	15.9	18.33	31,200
November 1–10	264	96	183	5.74	2.13	3,630

LONG RIVER BELOW SECOND LAKE AT PORT SNETTISHAM.

Location.—One-half mile downstream from outlet of Second Lake, 1 mile downstream from outlet of Long Lake, one-half mile upstream from head of Indian Lake; 2½ miles by trail and boat across Second Lake from cabins of the Speel River project at head of the North Arm of Port Snettisham, 42 miles by water from Juneau.

Drainage area.—33.2 square miles (measured on sheet No. 12 of the Alaska Boundary Tribunal maps, edition of 1895).

Records available.—November 11, 1915, to December 31, 1916.

Gage.—Stevens water-stage recorder on right bank one-half mile below outlet of Second Lake.

Discharge measurements.—At medium and high stages made from cable across river at gage; at low stages made by wading one-fourth mile downstream.

CHANNEL AND CONTROL.—At the gage the channel is deep and the current sluggish; banks are low and are overflowed at extremely high stages; bed smooth except for one large boulder. A rapid, 500 feet downstream, forms a well-defined and permanent control.

EXTREMES OF DISCHARGE.—Maximum stage recorded during period, 6.55 feet at 7 a. m., September 19 (discharge, 2,340 second-feet); minimum flow estimated from one discharge measurement and climatic data, 23 second-feet, February 13.

ICE.—Stage-discharge relation affected by ice during January, February, and March.

ACCURACY.—Stage-discharge relation permanent; affected by ice January 16 to April 2. Rating curve fairly well defined between 50 and 400 second-feet and well defined between 400 and 2,000 second-feet. Operation of water-stage recorder satisfactory throughout the open-water period except for short periods in December, 1915, and January, 1916. Daily discharge ascertained by applying to the rating table mean daily gage heights determined by inspecting the gage-height graph. Results good except for stages below 400 second-feet for which they are fair.

The area draining to Long River between Long Lake Outlet and this station comprise only 1.3 square miles, including First Lake and Second Lake. Because this area is at a low altitude and has no glaciers the run-off per square mile from it is greater in the early spring but much less in summer than that from the area above Long Lake, which is partly covered by glaciers.

Discharge measurements of Long River below Second Lake at Port Snettisham during the period Nov. 11, 1915, to Dec. 31, 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
1916.		*Feet.*	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Feb. 4[a]	G. H. Canfield		24	Oct. 12	G. H. Canfield	5.38	1,620
May 11	.....do	1.65	150	15	.....do	4.76	1,270
June 20	.....do	3.34	694	23	Gust Grosseth	3.00	517
25	.....do	4.28	1,050	27	.....do	2.95	493
30	.....do	4.65	1,230	Nov. 16	G. H. Canfield	1.80	155
July 25	Gust Grosseth	3.27	651	Dec. 15	Gust Grosseth	1.33	117
29	.....do	5.22	1,550	29	.....do	.65	56
Aug. 10	.....do	3.57	695				

[a] Stage-discharge relation affected by ice on control; ice in gage well prevented operation of float.

Daily discharge, in second-feet, of Long River below Second Lake at Port Snettisham for the period Nov. 11, 1915, to Dec. 31, 1916.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1915.			1915—Con.			1915—Con.		
1		88	11	102		21	157	83
2		114	12	93		22	196	100
3		134	13	128		23	108	118
4		131	14	151		24	94	96
5		112	15	126		25	89	89
6		118	16	114		26	85	83
7		174	17	106		27	85	89
8		126	18	103		28	84	96
9		96	19	91		29	82	96
10			20	105		30	85	83
						31		82

Daily discharge, in second-feet, of Long River below Second Lake at Port Snettisham for the period Nov. 11, 1915, to Dec. 31, 1916—Continued.

Day.	Jan.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1916.										
1	80	87	172	700	1,090	1,160	820	365	158	90
2	70	128	205	760	975	975	800	263	133	89
3	70	151	272	908	840	862	740	194	115	85
4	60	123	275	975	800	780	680	326	112	83
5	62	100	185	780	740	840	840	492	113	82
6	60	109	165	740	740	862	1,160	412	205	79
7	56	154	170	700	720	908	1,020	320	176	76
8	56	136	148	580	720	872	840	275	129	77
9	56	138	138	468	740	800	820	266	121	75
10	56	130	143	387	760	760	1,690	296	110	74
11	56	123	152	485	780	800	1,550	560	96	73
12	56	123	165	506	780	1,110	1,110	1,520	88	72
13	56	144	181	720	760	1,520	952	1,380	86	73
14	56	138	183	930	740	1,690	1,180	1,180	98	109
15	56	128	176	1,040	740	1,380	975	1,300	187	113
16	....	120	190	975	760	1,040	820	975	179	104
17	....	106	227	885	820	800	840	660	249	108
18	....	110	252	840	885	660	1,410	502	249	120
19	....	104	281	740	862	840	2,110	780	201	111
20	....	100	308	680	800	1,280	1,630	952	284	108
21	....	115	335	680	760	1,600	1,300	740	192	121
22	....	119	305	700	700	1,440	1,020	640	150	100
23	....	114	272	780	620	1,260	1,060	540	134	83
24	....	142	257	930	580	1,600	1,020	496	128	71
25	....	136	275	1,090	620	1,380	975	680	125	67
26	....	130	278	1,330	780	1,150	862	660	117	64
27	....	157	275	1,460	862	1,060	862	513	117	64
28	....	152	305	1,460	1,020	1,020	952	560	102	63
29	....	169	408	1,460	1,460	952	740	412	96	69
30	....	172	520	1,230	1,660	908	520	290	96	79
31	....	....	612	....	1,380	840	....	194	....	96

NOTE.—Discharge estimated from climatic records and comparison with records of flow for streams in adjacent drainage basins and one discharge measurement made Feb. 4, as follows: Dec. 10–20, 1915, 85 second-feet; Jan. 16–31, 40 second-feet; Feb. 1–13, 24 second-feet; Feb. 14–29, 70 second-feet; and Mar. 1–31, 50 second-feet.

Monthly discharge of Long River below Second Lake at Port Snettisham for the period Nov. 11, 1915, to Dec. 31, 1916.

[Drainage area 33.2 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
1915.						
November 11–30	196	82	109	3.28	2.44	4,320
December	....	....	98.2	2.96	3.41	6,040
1916.						
January	....	....	49.9	1.50	1.73	3,070
February	....	....	49.4	1.49	1.61	2,840
March	....	....	50	1.51	1.74	3,070
April	172	87	129	3.89	4.34	7,680
May	612	138	253	7.62	8.78	15,600
June	1,460	387	864	26.0	29.01	51,400
July	1,660	580	855	25.8	29.74	52,600
August	1,690	660	1,070	32.2	37.12	65,800
September	2,110	520	1,040	31.3	34.92	61,900
October	1,520	194	605	18.2	20.98	37,200
November	284	86	145	4.37	4.88	8,630
December	121	63	86.4	2.60	3.00	5,310
The year	2,110	....	434	13.1	177.85	315,000

SPEEL RIVER AT PORT SNETTISHAM.

Location.—At entrance of canyon one-fourth mile downstream from mouth of Long River, and 8 miles upstream from tide flats and the cabins of the Speel River Project (Inc.), which are at head of north arm of Port Snettisham, and 42 miles by water from Juneau.

Drainage area.—Not measured.

Records available.—July 1 to December 31, 1916.

Gage.—Stevens water-stage recorder 150 feet to the left of the constriction of the river at the entrance of the canyon. The gage is reached from cabins of the Speel River Project by trail to head of Second Lake, boat across Second Lake, trail to head of Indian Lake, boat across Indian Lake, trail down Long River and Indian River to canyon, and cable across river near entrance of the canyon—a total distance of about 7 miles.

Discharge measurements.—At all stages made from cable having a clear span of 400 feet across river, one-half mile below gage and one-fourth mile below lower end of canyon.

Channel and control.—For several miles above the canyon the river flows in several channels through a wide, flat, sandy valley in which the channels are continually shifting. The river is constricted from a width of 500 feet to 75 feet at entrance of canyon. This constriction of channel and rock outcrop at entrance of canyon form a very sensitive and permanent control. The extreme range in stage is 28 feet. Above a stage of 22 feet part of the flow passes through a secondary channel (the bed of which is rock overgrown with brush) which begins near gage and rejoins main channel at lower end of canyon. Below a stage of about 4 feet water from stream does not reach the well except by seepage through gravel. Stage-discharge relation is therefore not permanent for stages below 4 feet. At the gaging cable the bed of the river is gravel, with one large rock outcrop near middle of stream. The current is very swift and carries a large quantity of sand in suspension.

Ice.—Ice does not form at control, but so much frost forms in gage shelter and on metal parts of gage that the gage does not operate satisfactorily during the winter.

Accuracy.—Stage-discharge relation permanent except for stages below about 1,000 second-feet, when frequent measurements are necessary to estimate the flow. Rating curve fairly well defined between 1,200 and 10,000 second-feet; extended above 10,000 second-feet. Operation of water-stage recorder not satisfactory for periods indicated in footnote to daily-discharge table because of the frequent stopping of clock, owing to the binding of paper-supply roll. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph. Results fair for periods when gage was operating satisfactorily; poor for periods when clock was not running.

Discharge measurements of Speel River at Port Snettisham during the period July 1 to Dec. 31, 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
July 12	G. H. Canfield.........	12.80	5,020	Oct. 30	Gust Grosseth.........	5.7	1,340
27	Gust Grosseth.........	14.13	5,860	Nov. 8	.....do.................	....	768
Aug. 16	.....do.................	13.25	4,870	14	G. H. Canfield.........	2.18	470
Sept. 1	G. H. Canfield.........	14.90	6,350	15	.....do.................	5.70	1,580
Oct. 12	.....do.................	16.75	9,140	Dec. 20	Gust Grosseth.........	1.20	401
24	Gust Grosseth.........	8.96	2,660				

Daily discharge, in second-feet, of Speel River at Port Snettisham for the period July 1 to Dec. 31, 1916.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Day.	July.	Aug.	Sept.	Oct.	Nov.
1		6,360	6,360			16	5,140	5,220	5,060	4,070	1,420
2		5,220	5,950			17	5,480	4,370	5,750	2,900	1,420
3		5,060	5,060			18	5,300	4,010	10,300		1,320
4		4,980	4,620			19	4,980	5,140	12,600		1,250
5		5,220	5,220			20	4,900	7,160			
6		5,570	6,050			21	4,760	10,700			
7		5,660	4,690			22	4,430	8,330			
8		5,220	4,310			23	4,130	8,610			
9		4,980	4,430			24	4,130	11,400		2,680	
10		5,300	10,500			25	4,690	10,100		3,230	
11		5,750	7,790	2,680		26	5,570	9,660			
12		8,190	5,850	7,530		27	6,250	8,050			
13		11,200	5,390	6,580		28	6,920	7,920			
14		11,700	6,250	5,570	470	29	9,200	7,400			
15	4,980	7,040	5,300	5,750	1,490	30	8,750	6,580			
						31	7,530	6,360			

NOTE.—Discharge estimated by comparison with records of flow for streams in adjacent drainage basins, as follows: July 1-14, 5,070 second-feet; Sept. 20-30, 5,920 second-feet; Oct. 1-10, 1,560 second-feet; Oct. 8-23, 3,370 second-feet; Oct. 26-31, 2,130 second feet; Nov. 1-13, 612 second-feet; Nov. 20-30, 680 second-feet; and Dec. 1-31, 420 second-feet.

Monthly discharge of Speel River at Port Snettisham for the period July 1 to Dec. 31, 1916.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
July	9,200	4,130	5,420	333,000
August	11,700	4,010	7,050	433,000
September	12,600		6,220	370,000
October	7,530		2,890	178,000
November			760	45,200
December			420	25,800
The period				1,380,000

GRINDSTONE CREEK AT STEPHENS PASSAGE.

Location.—On north shore of Stevens Passage between Point Bishop and Point Salisbury, one-fourth mile west of mouth of Rhine Creek and 11 miles by water from Juneau.

Drainage area.—Not measured.

Records available.—May 6 to December 31, 1916.

Gage.—Stevens water-stage recorder on left bank, 200 feet from tidewater, installed September 16. A Lietz seven-day graph water-stage recorder was used May 6 to June 17.

Discharge measurements.—At all stages made by wading either in the channel on the beach, which is exposed at low tide or 100 feet below gage at high tide.

Channel and control.—For a distance of one-fourth mile from tidewater the stream descends in a series of rapids and falls through a narrow rocky channel. The gage is at upper end of a turbulent pool between two falls, the lower of which forms a well-defined control. When gage was installed, logs were jammed in channel near upper end of pool.

Extremes of discharge.—Maximum stage recorded during periods of record, 4.95 feet at 9 a. m September 10 (discharge, about 416 second-feet); minimum stage recorded, 0.25 foot during period December 12-31, exact date not known (discharge, 11 second-feet).

ICE.—Stage-discharge relation not affected by ice.

ACCURACY.—Stage-discharge relation not permanent because logs occasionally lodged on the control and were washed away during high water. Discharge measurements made during the period May 6 to September 6 indicate that there was no material change at the control. On September 10 logs evidently lodged on the control. When they were cut loose on September 30, the water surface fell 0.2 foot, after which the discharge measurement indicated that the stage-discharge relation was the same as that before September 6. Additional logs were washed away by the high water October 12, after which there was no further change at the control. Rating curve used May 6 to June 16 and September 6 to October 11, fairly well defined between 18 and 80 second-feet; 0.2 foot was subtracted from gage heights September 10 to 29 before applying to rating table. Rating curve used October 12 to December 11 well defined between 10 and 120 second-feet.

Operation of Lietz gage not satisfactory because clock lost about 12 hours each week; operation of Stevens gage satisfactory except December 12 to 31, when paper stuck to guides. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph. Results below 100 second-feet fair; above 100 second-feet poor.

Discharge measurements of Grindstone Creek at Stephens Passage during the period May 6 Dec. 31. 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
May 9	G. H. Canfield	0.83	20.7	Oct. 20	G. H. Canfield	1.50	96
June 12	do	1.55	72	20	do	1.48	93
Sept. 6	do	1.22	51	Nov. 24	Brown and Canfield	.86	34.6
30	do	1.25	52				

Daily discharge, in second-feet, of Grindstone Creek at Stephens Passage for 1916.

Day.	May.	June.	Sept.	Oct.	Nov.	Dec.	Day.	May.	June.	Sept.	Oct.	Nov.	Dec.
1		78		44	41	19	16	45	75	56	66	29	
2		82		39	36	18	17	48		48	56	48	
3		103		37	32	18	18	48		54	60	49	
4		86		136	29	17	19	48		69	134	43	
5		83		84	28	16	20	44		56	101	36	
6	28	112	38	57	27	16	21	39		52	83	29	
7	25	98	27	50	28	16	22	34		52	77	26	
8	21	80	25	44	26	14	23	32		64	64	24	
9	22	68	48	40	23	12	24	32		56	74	32	
10	22	60	206	48	22	17	25	32		76	104	34	
11	22	75	77	126	21	18	26	32		85	87	26	
12	26	78	63	251	20		27	37		92	78	22	
13	34	95	102	110	20		28	49		97	77	22	
14	34	90	171	92	25		29	74		63	64	20	
15	37	91	81	84	42		30	73		50	52	19	
							31	73			47		

NOTE.—Discharge Dec. 12-31 estimated at 15 second-feet by comparison with records of flow for Carlson, Sheep, and Gold creeks. No record June 17 to Sept. 5.

Monthly discharge of Grindstone Creek at Stephens Passage for 1916.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
May 6-31	74	21	38.9	2,010
June 1-16	112	60	84.6	2,680
September 6-30	206	25	72.3	3,590
October	251	37	79.5	4,890
November	49	19	29.3	1,740
December			15.5	953

CARLSON CREEK AT SUNNY COVE.

Location.—At Sunny Cove on west shore of Taku Inlet, 20 miles by water from Juneau.

Drainage area.—22.26 square miles (determined by engineering department of Alaska Gastineau Mining Co. from surveys made by that company).

Records available.—July 18 to December 31, 1916.

Gage.—Stevens water-stage recorder on left bank, 2 miles from tidewater; inspected several times a week by employees of the Alaska Gastineau Mining Co.

Discharge measurements.—At high stages, made from cable across river one-half mile downstream from gage; at medium and low stages, by wading 500 feet upstream from gage.

Channel and control.—Above the gage the stream meanders in one main channel and several small channels through a flat, sandy basin about a mile long; just below gage channel contracts and stream passes over rocky falls that form a well-defined and permanent control. Point of zero flow, gage height −1.5 feet.

Extremes of discharge.—Maximum stage recorded during period, 6.15 feet September 18 (discharge, computed from an extension of rating curve, 2,850 second-feet); minimum stage, −0.53 foot November 13 (discharge, 58 second-feet.)

Ice.—Stage-discharge relation affected by ice in January and February.

Accuracy.—Stage-discharge relation permanent. Rating curve well defined between 90 and 1,200 second-feet, extended below 90 second-feet to point of zero flow and above 1,200 second-feet by estimation. Operation of water-stage recorder satisfactory except for a few days; as gage was visited several times a week, breaks in record caused by clock stopping were short. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation by averaging results obtained by applying to rating table mean gage heights for regular intervals of the day. Results good except for stages below 90 second-feet and above 1,200 second-feet for which they are fair.

Discharge measurements of Carlson Creek at Sunny Cove during the period July 18 to Dec. 31, 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
July 22	Canfield and Perkins	1.20	365	Sept. 28	G. H. Canfield	2.33	716
27	.....do	1.37	408	Oct. 7	.....do	.35	173
Sept. 5	.....do	2.90	888	Nov. 1	Canfield and Perkins	.14	128
28	G. H. Canfield	3.07	966	4	.....do	−.18	96

Daily discharge, in second-feet, of Carlson Creek at Sunny Cove for the period July 18 to Dec. 31, 1916.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	....	530	288	200	132	57	16	....	355	316	382	306	83
2	....	459	261	170	115	57	17	....	336	513	266	404	70
3	....	385	234	138	108	56	18	445	352	1,540	337	274	79
4	....	487	243	523	94	55	19	445	749	1,310	988	183	74
5	....	545	604	350	88	54	20	487	960	921	821	102	61
6	....	620	808	206	95	54	21	459	808	650	439	121	64
7	....	575	393	170	95	53	22	363	572	692	642	98	61
8	....	401	306	165	89	53	23	347	892	808	371	88	58
9	....	355	613	167	75	52	24	445	970	700	387	78	53
10	....	393	1,400	243	65	51	25	487	545	755	714	67	50
11	....	412	605	634	63	51	26	501	425	605	590	64	48
12	....	825	385	1,430	60	50	27	459	395	824	374	60	46
13	....	775	665	584	58	60	28	690	376	916	525	59	44
14	....	620	779	858	81	79	29	1,670	344	406	311	58	45
15	....	473	390	755	336	104	30	1,050	308	274	208	58	43
							31	605	286	....	155	....	43

Monthly discharge of Carlson Creek at Sunny Cove for 1916

[Drainage area, 22.26 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
July 18-31	1,670	347	604	27.1	14.11	16,800
August	970	286	533	23.9	27.55	32,800
September	1,540	234	640	28.8	32.13	38,100
October	1,430	138	455	20.4	23.52	28,000
November	404	58	122	5.49	6.12	7,260
December	104	43	58.2	2.61	3.00	3,600
The period	....	....	....	....	....	127,000

SHEEP CREEK NEAR THANE.

Location.—At lower end of flat basin, above diversion dam for flume leading to Treadwell power house at beach, and 1 mile by tramway and ore railway from Thane.

Drainage area.—4.57 square miles above gaging bridge (measured on United States Geological Survey map of Juneau and vicinity, edition of 1917).

Records available.—July 26 to December 31, 1916.

Gage.—Stevens water-stage recorder on right bank at pool formed by an artificial control just below small island three-tenths mile upstream from diversion dam. Recorder inspected once a week by an employee of the Alaska Gastineau Mining Co.

Discharge measurements.—At extremely high stages made from gaging bridge two-tenths mile downstream from gage; at low stages made by wading near bridge section. No streams enter between gage and measuring section but seepage inflow varies from a small amount to 10 per cent of total flow, the per cent of inflow usually being large after periods of heavy precipitation.

Channel and control.—The station is near lower end of flat basin through which the stream meanders in a channel having low banks and bed of sand and gravel. An artificial control was built 2 feet below intake for gage well to confine the flow in one channel during high water and to insure a permanent stage-discharge relation. The spillway of the control at low stages consists of a timber, 16 feet long, set in the bed of the stream. During medium and high stages another timber, 8 feet long, bolted at top near right end, forms part of the control. A 3-foot cut-off wall is driven at upstream face of spillway. There are wing walls at each end and an 8-foot apron extends downstream from control.

ICE.—Ice forms in the channel above and below, but not on the spillway of the control.

ACCURACY.—On July 29 high water probably caused a readjustment in the gravel bed of channel disturbed during the construction of the control. Rating curve used July 25 to 29, based on one discharge measurement and shape of subsequent curve. Rating curve used July 30 to October 8 based on nine discharge measurements and is fairly well defined. During this period the intake pipe was obstructed with gravel, and water surface in well was maintained at level of water surface in creek 10 feet upstream from control by seepage through gravel. After October 8, the intake pipe was kept open and the stage-discharge relation was permanent; rating curve used October 9 to December 31 based on 7 discharge measurements and is well defined below and poorly defined above 150 second-feet. Operation of water-stage recorder satisfactory; the gage was inspected at least once a week. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation by averaging results obtained by applying to rating table mean gage heights for regular intervals of the day. Results fair.

Discharge measurements of Sheep Creek near Thane during the period July 26 to Dec. 31, 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
July 21	Canfield and Perkins	1.00	50	Oct. 6	G. H. Canfield	0.90	55
Aug. 29	.....do	.95	61	9	.....do	.83	44
Sept. 2	Enoch Perkins	.84	47	20	.....do	1.16	126
14	G. H. Canfield	1.28	141	Nov. 6	.....do	.76	30
19	.....do	1.23	127	23	Brown and Canfield	.76	31
27	.....do	1.48	172	Dec. 22	C. O. Brown	.57	13.9
29	.....do	1.06	89	28	.....do	.51	11.3
Oct. 4	.....do	1.31	134				
6	.....do	.90	52				

Daily discharge, in second-feet, of Sheep Creek near Thane for the period July 26 to Dec. 31, 1916.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	....	80	48	59	36	21	16	....	63	78	74	38	16
2	....	74	43	50	45	19	17	....	59	72	55	55	16
3	....	64	45	45	43	18	18	....	59	111	71	43	17
4	....	80	48	108	36	19	19	....	93	122	149	43	16
5	....	86	78	68	34	19	20	....	93	100	127	41	15
6	....	100	102	55	30	18	21	....	87	82	100	36	14
7	....	85	59	50	32	17	22	....	76	91	133	30	13
8	....	66	50	47	29	15	23	....	108	102	92	29	12
9	....	63	88	45	28	14	24	....	126	87	105	29	12
10	....	68	227	49	23	14	25	....	82	126	139	30	12
11	....	63	102	97	22	14	26	52	74	104	89	28	12
12	....	97	87	246	23	14	27	50	68	143	41	23	12
13	....	97	129	108	23	14	28	107	68	115	67	25	11
14	....	82	153	120	27	14	29	129	63	82	38	25	11
15	....	70	93	97	39	17	30	100	59	68	39	23	11
							31	78	51	....	39	....	11

Monthly discharge of Sheep Creek near Thane for 1916.

[Drainage area, 4.57 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
August	126	51	77.5	17.0	19.60	4,770
September	227	43	94.5	20.7	23.09	5,620
October	246	38	83.9	18.4	21.21	5,160
November	55	22	32.3	7.07	7.89	1,920
December	21	11	14.8	3.24	3.74	910
The period						18,400

GOLD CREEK AT JUNEAU.

Location.—At highway bridge at lower end of Last Chance basin, 200 feet upstream from diversion dam of Alaska Electric Light & Power Co., and one-fourth mile from Juneau.

Drainage area.—9.47 square miles (determined by engineering department of Alaska Gastineau Mining Co., from surveys made by that company).

Records available.—July 20 to December 31, 1916.

Gage.—Stevens water-stage recorder on left bank at upstream side of highway bridge. A staff gage was installed September 19 on left wing wall of diversion dam 200 feet downstream and used in determining the time of changes in stage-discharge relation at the well gage.

Discharge measurements.—At medium and high stages made from gaging bridge suspended, at right angles to current, from floor of highway bridge; at low stages, made by wading near gage.

Channel and control.—Station is at lower end of a flat gravel basin three-fourths mile long. For 20 feet upstream from gage the stream is confined between the abutments of an old bridge, and for 15 feet downstream it is confined between the abutments of present bridge. For a distance of 130 feet farther downstream the stream is confined in a narrow channel which is not subject to overflow. Because of the steep gradient of channel opposite and for 150 feet below gage, a short stretch of the channel immediately below the gage acts as the control. The operation of the head gates of flume at diversion dam, 200 feet downstream, does not affect the stage-discharge relation at gage, but the swift current during high stages shifts the gravel in bed of stream, thereby causing changes in the stage-discharge relation.

Ice.—Stage-discharge relation not affected by ice.

Diversion.—Water diverted at several points upstream for power development is returned to creek above gage, except about one-second foot used by the Alaska Juneau Mining Co. The dam 200 feet downstream diverts water into the flume of the Alaska Electric Light & Power Co.

Regulation.—No storage reservoirs above station that regulate the flow.

Accuracy.—Stage-discharge relation changed during periods of high water; 20 discharge measurements and 4 simultaneous readings of water-stage recorder and staff gage at diversion dam were made during the period, by use of which rating curves have been constructed applicable as follows: July 24 to August 22, rating curve well defined below and poorly defined above 200 second-feet; August 24 to September 9, well defined below and poorly defined above 200 second-feet; September 11–17, well defined below and poorly defined above 250 second-feet; September 19 to October 11, well defined; October 13–24, well defined between 160 and 260 second-feet, and poorly defined above and below these limits; October 26 to December 31, well defined. The operation of the water-stage recorder was satisfactory throughout the period, as the gage was visited about every other day by an employee of the Alaska Gastineau Mining Co. Daily discharge ascertained by applying to the rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging the results obtained by applying to rating table mean gage heights for equal intervals of the day. Results fair.

Discharge measurements of Gold Creek at Juneau during the period July 20 to Dec. 31, 1916.

Date.		Made by—	Gage height, in feet.		Discharge.
			Staff gage at dam.	Water-stage recorder.	
					Sec.-ft.
July	20	Perkins and Canfield		1.66	166
	24	Canfield and Perkins		1.38	110
	26	do		1.54	145
Aug.	28	do		1.97	159
Sept.	1	Enoch Perkins		1.80	120
	4	do		1.70	104
	12	G. H. Canfield		1.75	137
	18	do		2.15	235
	18	do		2.68	445
	19	do		2.56	517
	19	do	0.93	1.98	305
	23	do	.97	1.97	308
	23	do	1.17	2.24	400
	26	do	.62	1.62	199
Oct.	2	do	.06	0.99	76
	9	do	.00	.90	64
	27	do	.66	1.57	209
Nov.	6	do		.61	34.5
Dec.	20	C. O. Brown		.30	15.9
	28	do		.08	8
Oct.	15			1.53	[a]228
	21			1.38	[a]180
	22			1.68	[a]250
	28			1.66	[a]227

[a] Simultaneous readings taken of water-stage recorder and staff gage; discharge ascertained from rating curve for staff gage.

Daily discharge, in second-feet, of Gold Creek at Juneau for the period July 20 to Dec. 31, 1916.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	....	213	127	95	70	20	16	....	150	150	167	78	15
2	....	189	117	80	59	18	17	....	142	190	125	140	17
3	....	150	108	69	47	16	18	....	146	380	127	100	18
4	....	191	108	225	42	16	19	....	297	406	330	76	16
5	....	224	197	134	41	15	20	166	323	282	280	63	15
6	....	271	234	86	37	14	21	150	291	234	182	48	13
7	....	235	147	74	40	14	22	120	238	260	240	38	11.5
8	....	164	125	67	33	14	23	120	288	322	170	34	10
9	....	148	198	67	28	12	24	130	286	232	187	32	9.5
10	....	171	494	99	23	11	25	135	202	273	290	35	8.5
11	....	174	222	219	24	9.5	26	159	181	222	212	29	8
12	....	310	140	545	24	10	27	155	173	254	152	25	8
13	....	300	220	227	22	13	28	262	173	325	215	23	8
14	....	235	325	253	29	22	29	472	158	182	146	23	9
15	....	184	170	248	91	19	30	337	136	122	104	21	10
							31	229	127	....	84	....	9.5

NOTE.—Discharge July 21-24 estimated by comparison with record of flow of Carlson Creek at Sunny Cove.

Monthly discharge of Gold Creek at Juneau for the period July 20 to Dec. 31, 1916.

[Drainage area, 9.47 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
July 20-31	472	120	203	21.4	9.55	4,830
August	323	127	209	22.1	25.48	12,900
September	494	108	226	23.9	26.67	13,400
October	545	67	177	18.7	21.56	10,900
November	140	21	45.8	4.84	5.40	2,730
December	22	8	13.2	1.39	1.60	812
The period	....	....	....	....	....	45,600

SHERMAN CREEK AT KENSINGTON MINE.

LOCATION.—At Kensington mine, on east shore of Lynn Canal, one-fourth mile downstream from mouth of Ophir Creek, 1 mile above mouth of creek, and 12 miles north of Berners Bay. Creek at this point flows through a flume 10 feet wide and 20 feet long, constructed for the purpose of affording a better section for making discharge measurements.

DRAINAGE AREA.—3.65 square miles (measured on topographic map).

RECORDS AVAILABLE.—August 17, 1914, to December 31, 1916.

GAGE.—Vertical staff graduated to tenths and half-tenths, fastened in center of flume, about half the distance along tramway from beach to main camp of mine; read by an employee of Kensington Mining Co.

DISCHARGE MEASUREMENTS.—Made near lower end of flume in which gage is located. At high stages measuring section is poor because of wave pulsations in flume.

CHANNEL AND CONTROL.—The natural bed of channel upstream and downstream from gage is very rough. The entire flow at all stages passes through the flume. A free fall at lower end of flume forms a permanent control for gage. Point of zero flow, zero gage height.

Extremes of discharge.—1914–1916: Maximum stage recorded, 2.00 feet October 15, 1915 (discharge determined from an extension of rating curve, 208 second-feet); minimum stage, 0.20 foot January 25, 27, 29, February 2, 4, 8, and 10, 1916 (discharge, 2.8 second-feet).

Ice.—Stage-discharge relation not affected by ice.

Accuracy.—Stage-discharge relation permanent. Rating curve well defined below 150 second-feet; extended from 150 to 208 second-feet. Gage read to hundredths generally once every other day except October 5, 1914, to February 7, 1915, when it was read only twice a week. Daily discharge for days when gage was read ascertained by applying gage height to rating table. Discharge for other days determined by interpolation or by comparison with records of flow for streams in adjacent drainage basins. Results fair.

Discharge measurements of Sherman Creek at Kensington mine during the period Sept. 9 to Dec. 31, 1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
Sept. 9	G. H. Canfield	0.62	19.1	Oct. 13	J. A. Wilcox	0.85	43
Oct. 12	J. A. Wilcox	1.58	145	Nov. 9	G. H. Canfield	.44	10.4
12	.....do	1.19	89				

Daily discharge, in second-feet, of Sherman Creek at Kensington mine for the period Aug. 17, 1914, to Dec. 31, 1916.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1914.						1914.					
1	....	33	18	23	8	16	....	18	30	....	12.0
2	....	33	18	22	6.6	17	39	17	20	....	6.0
3	....	31	14	20	6.6	18	31	16	15	....	6.0
4	....	31	21	18	6.6	19	23	16	17	....	6.0
5	....	34	23	17	6.6	20	34	15	19	....	5.9
6	....	31	24	15	6.6	21	27	14	21	....	6.0
7	....	27	25	14	6.2	22	21	44	23	....	6.0
8	....	23	....	15	5.7	23	27	75	23	....	12.0
9	....	34	....	23	5.3	24	34	31	60	....	6.0
10	....	56	....	21	5.2	25	70	34	60	....	5.0
11	....	31	....	19	5.2	26	39	38	23	....	5.0
12	....	31	47	18	5.1	27	48	34	25	....	5.0
13	....	27	128	17	5.0	28	56	40	32	14	4.8
14	....	22	128	16	5.0	29	47	31	25	12	4.6
15	....	18	50	14	5.0	30	33	18	24	10	4.4
						31	33	....	23	....	4.2

Daily discharge, in second-feet, of Sherman Creek at Kensington mine for the period Aug. 17, 1914, to Dec. 31, 1916—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1915.												
1	5.0	5.0	3.5	22	12	37	22	28	37	50	20.0	7.9
2	10.0	4.7	4.4	26	11	40	24	31	50	70	26.0	8.8
3	26.0	4.4	5.3	44	30	43	26	24	63	90	28.0	10.0
4	26.0	4.3	5.8	63	50	46	24	17	44	73	31.0	11.0
5	15.0	4.2	6.2	76	56	50	23	17	26	56	24.0	9.5
6	8.8	4.1	16.0	90	63	48	20	17	22	46	18.0	8.0
7	10.0	4.0	26.0	72	56	47	18	17	18	37	14.0	9.0
8	11.0	4.0	22.0	43	50	39	18	17	17	28	11.0	10.0
9	12.0	4.0	18.0	32	44	31	18	36	16	18	11.0	8.5
10	14.0	4.4	22.0	22	37	34	20	56	16	18	11.0	7.0
11	12.0	4.7	26.0	36	37	37	22	56	15	18	10.0	7.0
12	10.0	4.4	20.0	50	37	46	24	56	14	61	8.8	7.0
13	5.9	4.2	13.0	66	50	56	26	120	14	104	13.0	7.0
14	9.0	4.1	13.0	83	63	60	26	180	16	156	18.0	7.0
15	11.0	4.0	13.0	70	56	63	26	120	17	208	16.0	6.6
16	13.0	3.8	18.0	56	50	51	26	63	18	142	13.0	6.2
17	18.0	3.7	22.0	48	48	39	26	53	18	76	13.0	6.6
18	12.0	3.7	49.0	40	46	36	26	43	28	49	13.0	7.0
19	9.0	3.7	76.0	36	44	33	26	37	37	22	14.0	7.5
20	7.0	3.6	90.0	31	43	35	28	31	27	20	16.0	8.0
21	6.0	3.5	104.0	26	42	37	29	28	17	18	17.0	7.5
22	6.0	3.5	68.0	22	40	30	26	26	54	17	18.0	7.0
23	6.0	3.5	31.0	20	38	22	23	22	90	16	17.0	6.4
24	5.9	3.5	28.0	18	37	22	24	18	110	14	16.0	5.9
25	5.5	3.5	26.0	18	44	23	24	18	133	13	14.0	5.6
26	5.1	3.4	30.0	17	50	22	26	18	118	13	13.0	5.3
27	4.7	3.3	33.0	15	44	20	28	47	104	13	11.0	5.3
28	4.8	3.4	31.0	13	37	28	30	76	90	14	8.8	5.3
29	4.9	......	29.0	12	34	37	31	54	76	16	7.9	5.8
30	5.1	......	24.0	12	31	30	28	31	63	14	7.0	5.3
31	5.3	......	18.0	......	34	......	24	34	......	13	......	5.0
1916.												
1	4.7	2.8	4.7	5.3	80	83	......	......	87	......	14.0	8.8
2	5.0	2.8	4.6	5.3	97	90	......	......	84	......	11.0	7.0
3	5.3	2.8	4.4	7.0	76	97	......	......	81	......	11.0	6.2
4	5.3	2.8	4.2	8.8	56	82	......	......	31	......	11.0	5.3
5	5.3	3.0	4.0	10.0	39	67	......	......	81	......	10.0	5.3
6	5.3	3.3	3.8	11.0	22	62	......	56	28	......	8.8	5.3
7	5.3	3.0	3.5	10.0	22	58	......	53	26	......	7.9	5.3
8	5.0	2.8	3.5	10.0	22	56	......	50	24	......	7.0	5.3
9	4.7	2.8	3.5	12.0	20	54	......	45	23	16	7.0	5.0
10	4.4	2.8	3.5	13.0	18	58	......	40	......	22	7.0	4.6
11	4.0	3.0	3.5	11.0	16	63	......	70	......	63	6.2	4.3
12	4.0	3.3	3.4	8.8	15	113	......	101	......	148	5.3	4.0
13	4.0	3.8	3.3	13.0	19	163	......	101	......	43	8.2	10.0
14	3.8	4.4	3.3	17.0	23	128	......	101	......	63	11.0	16.0
15	3.5	4.2	3.3	12.0	38	94	......	70	63	47	186.0	11.0
16	3.5	4.0	3.3	7.6	54	90	......	40	70	31	134.0	5.3
17	3.5	34	3.3	7.3	76	86	......	40	76	37	83.0	7.0
18	3.5	63	3.3	7.0	97	78	......	40	83	43	66.0	6.4
19	3.5	50	3.3	7.3	84	70	......	55	90	53	50.0	5.7
20	3.4	37	3.3	7.6	70	70	......	70	90	63	36.0	5.3
21	3.3	25	3.3	9.3	63	70	......	54	90	70	22.0	4.6
22	3.2	13	3.2	11.0	56	73	......	37	104	76	18.0	4.0
23	3.1	12	3.1	14.0	54	76	......	64	118	80	13.0	4.0
24	3.0	10	3.1	16.0	53	97	......	90	126	83	12.0	4.0
25	2.8	8.5	3.1	20.0	53	118	......	72	133	70	11.0	4.0
26	2.8	7.0	3.1	23.0	53	104	......	54	112	56	10.0	4.0
27	2.8	6.4	3.1	45.0	56	90	......	46	90	70	8.8	......
28	2.8	5.9	3.1	67.0	58	83	......	37	76	83	8.8	......
29	2.8	5.3	3.1	65.0	65	76	......	32	40	52	8.8	......
30	2.8	......	4.2	63.0	72	60	......	28	30	22	8.8	......
31	2.8	......	5.3	......	78	......	......	32	......	18	......	......

NOTE.—Discharge estimated, because gage was not read, by comparison with records of flow for streams in adjacent drainage basins, as follows: Oct. 8–11 and Nov. 16–27, 1914, 20 second-feet; July 1–31, 50 second-feet; Aug. 1–5, 48 second-feet; Sept. 10–14, 45 second-feet; Oct. 1–8, 29 second-feet; and Dec. 27–31, 1916, 5 second-feet.

Monthly discharge of Sherman Creek at Kensington mine for the period Aug. 17, 1914, to Dec. 31, 1916.

Drainage area, 3.65 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
1914.						
August 17-31	70	21	37.5	10.3	5.74	1,120
September	75	14	30.1	8.25	9.20	1,790
The period	....	....	....	....	....	....
1914-15.						
October	128	14	32.8	8.99	10.36	2,020
November	....	....	18.3	5.01	5.59	1,090
December	12	4.2	6.05	1.66	1.91	372
January	26	4.7	9.81	2.69	3 10	603
February	5.0	3.3	3.95	1.08	1.12	219
March	104	3.5	28.7	7.86	9.06	1,760
April	90	12	39.3	10.8	12.05	2,340
May	63	11	42.4	11.6	13.37	2,610
June	63	20	38.1	10.4	11.60	2,270
July	31	18	24.6	6.74	7.77	1,510
August	180	17	44.9	12.3	14.18	2,760
September	133	14	45.6	12.5	13.95	2,710
The year	180	3.3	28.0	7.67	104.06	20,300
1915-16.						
October	208	13	48.5	13.3	15.33	2,980
November	31	7.0	15.3	4.19	4.68	910
December	11	5.0	7.21	1.98	2.28	443
January	5.3	2.8	3.85	1.05	1.21	237
February	63	2.8	11.3	3.10	3.34	650
March	5.3	3.1	3.57	.978	1.13	220
April	67	5.3	17.5	4.79	5.34	1,040
May	97	15	51.8	14.2	16.37	3,190
June	163	54	83.6	22.9	25.55	4,970
July	....	....	50	13.7	15.79	3,070
August	101	28	55.4	15.2	17.52	3,410
September	133	....	62.7	17.2	19.19	3,730
The year	....	2.8	34.2	9.37	127.73	24,800
1916.						
October	148	....	49.7	13.6	15.68	3,060
November	186	5.3	26.7	7.32	8.17	1,590
December	16	....	5.89	1.61	1.86	362
The period	....	....	....	....	....	5,010

MISCELLANEOUS MEASUREMENTS.

Miscellaneous discharge measurements in southeastern Alaska, 1915–16.

Date.	Stream.	Tributary to or discharging into—	Locality.	Gage height.	Discharge.
				Feet.	*Sec.-ft.*
1915. July 14	Reynolds Creek	Copper Harbor	Just above stream entering from right near tidewater, three-fourths mile from Coppermount, Prince of Wales Island.		15
1916. Jan. 11	Swan Creek	Carroll Inlet	1 mile upstream from beach, on east shore and 1 mile from head of Carroll Inlet, Revillagigedo Island.		64
26	Gokatchin Creek	Thorne Arm	Channel at low tide at mouth of creek one-fourth mile east of Sea Level, Revillagigedo Island.		18
Feb. 4	Long Lake outlet	Speel River	New gaging station below Second Lake, Speel River Project (Inc.).		24
4	Crater Lake outlet	Port Snettisham	Channel at low tide at mouth of stream from Crater Lake, Speel River project.		5
5	Speel River	do	Tide flats at Speel Point during low tide, one-half mile from cabins of the Speel River project.		150
7	Grindstone Creek	Stephens Passage	Channel at low tide at mouth of stream between Point Salisbury and Point Bishop, north shore Stephens Passage, 11 miles southeast of Juneau.		3.2
7	Rhine Creek	do	do		1.6
Mar. 10	Myrtle Lake outlet	Moira Sound	Channel at low tide at mouth of creek, 1 mile east of Niblack, Prince of Wales Island.		50
Apr. 6	Gokatchin Creek	Thorne Arm	Same location as on Jan. 26		100
May 9	Rhine Creek	Stephens Passage	Same location as on Feb. 7	0.90	19.3
June 1	Rust Lake outlet	Khaz Bay	Channel at low tide at mouth of creek, 500 feet below power house of Chichagof Mining Co., Chichagof Island.		265
12	Rhine Creek	Stephens Passage	Same location as on Feb. 7	2.28	78
Aug. 4	Gokatchin Creek				88
Sept. 3	Bear Lake outlet	Taku Harbor	Outlet of Bear Lake, 2 miles upstream from tidewater at cannery, 22 miles southeast of Juneau.		8.6
8	Davies Creek	Cowee Creek	½ mile above Cowee Creek, at Berners Bay, mainland.		99

MINING IN THE LOWER COPPER RIVER BASIN.

By Fred H. Moffit.

COPPER MINING IN CHITINA VALLEY.

INTRODUCTION.

During the summer of 1916 the writer visited most of the copper prospects of Chitina Valley (Pl. X, p. 156) to study their geology and learn what progress had recently been made in their development. The present activity of the copper market is reflected in the district by increased interest in prospecting for copper, and more particularly by the efforts of copper producers to maintain a maximum production of high-grade ore. No new mines that yielded a recorded output were opened in 1916, but shipments were made for the first time from a number of properties, some of which may become steady producers. The prospects will be described in the order in which they were visited, those in the western part of the field being considered first and those in the eastern part last. No attempt will be made to describe in detail all the prospects, nor is the space given to the description of any particular prospect an indication of its relative value. Some claims are described rather fully, because recent work on them has disclosed significant geologic facts or geologic relations, and one or two that have not been described before are described in detail.

The copper ores of the district extending from Kotsina River to Nizina are chiefly bornite, chalcopyrite, chalcocite, and oxidation products such as malachite, azurite, and covellite. Native copper, enargite, copper oxides, and some other copper-bearing minerals, among them tetrahedrite, are associated in places with the more common minerals first named.

Most of the copper deposits are found in the succession of ancient lava flows, long known as the Nikolai greenstone, that underlies the massive Upper Triassic (Chitistone) limestone of Chitina Valley. These lava flows are not a geologic unit, as was formerly supposed, but include in their lower part sedimentary beds and fragmental volcanic rocks deposited in water. Copper minerals occur in the older as well as the younger flows, although they are probably more common in the younger. At a few places deposits of copper minerals have been found in the limestone (Chitistone) overlying the lava flows. The Kennecott-Bonanza and Jumbo mines are the best known of such deposits, and because of their great production of high-grade ore they have drawn particular attention to the limestone as a source of copper. Most of the copper prospects of Chitina Valley have already been described in more or less detail in publications of the U. S. Geological Survey.[1]

KOTSINA RIVER.

Most of the copper deposits of Kotsina River are in the upper part of the basin. The basin of the Kotsina, however, includes Elliott Creek, one of its lower tributaries, which by position and topography is detached from the main valley and is cut off from easy communication with it.

The copper claims of upper Kotsina River are, for the most part, in the hands of a few owners, who have done the assessment work required to hold the properties, but have not had the means to develop them and demonstrate their value. Claims are held on Copper Creek, Kluvesna River (including Mineral Creek), Kotsina River, and Granite, Surprise, Peacock, Roaring, Amy, and Rock creeks, tributaries to the Kotsina. A few claims have been dropped recently and others will probably be dropped, owing to the failure of the owners to interest capitalists in them. Although copper is the principal metal that has been sought in this district, silver has been found at one locality, where it may be present in sufficient quantity to make it of economic importance. It is contained in the mineral tetrahedrite and occurs in a zone of faulting and fracture west of the large granite intrusion between Kotsina and Kluvesna rivers. Several short tunnels have been driven on the claims, but because of the numerous faults they have not given a clear idea of the extent of the mineralization and the direction of the veins.

ELLIOTT CREEK.

The copper prospects of Elliott Creek are the property of the Hubbard Elliott Copper Co. and are represented by over 50 claims, some of which are patented. These claims extend along the upper part of Elliott Creek, principally on its north side, for nearly 6 miles. Bornite, chalcopyrite, and chalcocite are the most common copper minerals of the deposits.

For three years mining on Elliott Creek has consisted principally of assessment work on unpatented claims and the extension of the Albert Johnson tunnel on Deception Creek. When visited in August, 1916,

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[1] Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, 1909. Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, 1911.

1917

this tunnel had been run to a length, not including crosscuts, of 1,076 feet, but preparations were under way for resuming work on it within a few days, and no doubt either the tunnel or a crosscut was extended considerably before the season ended. Work in the tunnel was not begun till late in the summer because of delays in the delivery of powder and because of difficulties in shipping that arose from labor troubles in Seattle. Power for the drills used in the tunnel is supplied by a small compressor plant driven by a gasoline engine. This equipment makes it possible to extend this tunnel much more rapidly and economically than the Elizabeth and Curtis tunnels, where hand drills were employed.

As the Albert Johnson tunnel, nearly all of which is in greenstone, approached the contact of the greenstone with the overlying limestone (Chitistone) shattered country rock and faulted-in masses of the limestone and shale that normally overlie the Chitistone limestone were encountered. A little farther from the face of the tunnel the drillers met a zone of crushed greenstone, which required timbering. This greenstone contains a little native copper, the only native copper that has yet been found in the tunnel. The ore that was exposed at several places by the tunnel is bornite and chalcopyrite in irregular veins which form part of a sheeted zone in the greenstone and are cut by faults later than the time of copper deposition. Because of this later faulting few of the copper-bearing veins can be followed far and many of them end abruptly against a wall of greenstone.

The Elliott Creek claims are now connected with Strelna by a new trail, which is much better than the one formerly used and which avoids the swampy areas traversed by the old trail.

KUSKULANA RIVER.

The copper prospects of Kuskulana River include the Copper Mountain group, at the head of Clear Creek; prospects on Porcupine Creek and Nugget Creek; the Finch group, between the forks of Kuskulana Glacier; the Pierson claims; the London and Cape claims, south of Trail Creek; the MacDougall claims; the Rarus group; and the Berg claims, or claims of the North Midas Copper Co., east of the Kuskulana and opposite the mouth of Clear Creek. None of these claims is now producing copper, but shipments of ore have been made from Nugget Creek.

The Copper Mountain group belongs to the Great Northern Development Co. and includes 58 claims on Clear and Porcupine creeks. Patent had been granted on 35 of these claims at the time of visit, and was expected soon on the remaining 23 claims. The development work consists of four main tunnels having a total length of more than a mile. Most of the work on these tunnels was done several years ago, but owing to the destruction of the power plant by a snowslide and to uncertainty about the granting of patents, work was discontinued except so much as was required to hold the ground.

The copper ore is chalcopyrite or copper-bearing pyrite of low grade and is associated with a large body of diorite intruded in greenstone. Sulphides, especially pyrite, are present in the intrusive, but most of the copper sulphide is in the greenstone near the borders of the intrusive, where it occurs with pyrite in irregular veins and stringers and in small particles scattered through the greenstone. The ore is of low grade and must be mined on a large scale in order to be mined profitably. The owners expect to resume work when all the patents have been granted and propose to erect a plant to experiment with methods for saving the copper.

Several claims, in addition to those of the Great Northern Development Co., have been staked on Porcupine Creek. Most of them are near the borders of the intrusive rock and show the same copper minerals as the claims on Clear Creek. Several short tunnels have been started, but no extensive development work has been undertaken.

The claims on Nugget Creek belong to the Alaska Consolidated Copper Co. and are the only claims in Kuskulana Valley from which ore has been shipped. For a number of years the mining on this creek has been centered in the Valdez claim. The copper minerals occur along a well-defined fault which strikes N. 68° W. and dips 80° E. The common minerals are bornite, chalcopyrite, and pyrite. In places the copper minerals are accompanied by a gangue of calcite. Movement has taken place along the fault since the ore was deposited, so that in places both sides of the ore body are bounded by fault planes. The best ore so far encountered was at the surface and consisted of bornite and chalcopyrite in calcite. It was mined out and shipped to the smelter. As the deposits were followed downward the bornite diminished and the copper content became smaller, and along with this change pyrite appeared.

The development work now includes drifts at the 35-foot, the 50-foot, the 105-foot, and the 160-foot levels. The main or 160-foot level, called also the Lucky Boy tunnel, opens to the surface. A shaft 140 feet deep was sunk in the main level and a crosscut to the north was started from the bottom. This crosscut had been driven 60 feet at the time of visit in August and was advanced considerably before the summer ended.

The Finch group, on the mountain point between the forks of Kuskulana Glacier, belongs to the Alaska United Exploration Co. It includes 10 claims on which 3 short tunnels were driven and numerous open cuts were made. The copper minerals, which are chiefly bornite and chalcocite, are found along a shear zone trending approximately northeast. Most of the prospecting has been done along this shear zone. A large disk-shaped mass of ore, a mixture of granular chalcocite, bornite, and quartz, is exposed near the highest tunnels, about 1,300 feet above the forks of the glacier. Its peculiar granular texture distinguishes it from any other ore in Chitina Valley known to the writer. It seems to be faulted off from a larger ore body, but the development work has not yet revealed the extension of the vein. Approximately 350 feet of tunnel has been driven on the Finch group.

The McConnell-Johnson or Mayflower claims are on the east side of Kuskulana Glacier, about 2½ miles above its lower end. The principal copper showing is about 1,000 feet above the glacier, on the east side of a deep gulch. The country rock is greenstone and is cut by a fault which strikes N. 50° E. and dips 75° N. Other faults and numerous fissures and joint planes are present, but the fault mentioned is the most prominent and is clearly defined by a steep, narrow gulch which follows it and was caused by it. Bornite, accompanied by quartz and epidote in variable quantity, is deposited along the main fault and in some of the minor faults, particularly near the intersection with a north-south fault. A few small, isolated lenses of bornite were also noticed in the greenstone away from the main fault. No physical connection between them and the fault was seen.

The development work includes several open cuts along the gulch, especially at the place where the ore is best exposed, and a tunnel on the east side of the gulch 75 feet long and 300 feet lower than the principal showing of ore.

The Pierson claims are near the lower end of Kuskulana Glacier and on the east side of the river, about 500 feet above the river level. Mineralization took place along the contact of the Chitistone limestone and a small dike or sill that lies between the limestone and the greenstone. The contact is a fault contact. A little copper staining is present, but free gold is reported by the owners and is regarded by them with greater favor than the copper. A short tunnel driven along the contact was caved at the time of visit and could not be examined.

The property of the London & Cape Co. includes 14 claims on the ridge southwest of Trail Creek. These claims were patented a number of years ago and no work has been done on them since the patents were issued. Copper stains are seen along fracture planes that cut the quartz-diorite country rock on the top of the ridge. A little work was done on the ridge, but more is represented by a tunnel on the Trail Creek side of the ridge, between 2,000 and 3,000 feet above the mouth of the creek. This tunnel was closed when visited, but is reported to be 245 feet long. It was begun to test the downward continuation of ore-bearing fractures on the ridge, but was not continued after the patents were obtained and is said to have no showing of copper.

The Rarus group was formerly part of the holdings of the Alaska Consolidated Copper Co., which dropped it in 1915, and it was restaked in 1916 by others. It is on the southeast side of Kuskulana River nearly 2 miles below Trail Creek. A tunnel 433 feet long and about 1,200 feet above the Kuskula was driven in a much faulted and metamorphosed mass of limestone and igneous rocks, including quartz diorite, hornblende-augite porphyry, and possibly greenstone. Some of the limestone is altered to highly garnetiferous metamorphic rock and some is silicified. A large quantity of magnetite in veins and irregularly shaped masses was introduced during the process of metamorphism. The ore body consists of pyrite and chalcopyrite or copper-bearing pyrite. Above the tunnel, as far as the base of the massive Jurassic conglomerate, the country rock is stained with iron and copper. The claims of the Rarus group include part of an area of contact-metamorphic rocks that extends northeast and southwest from the Rarus tunnel and that presents geologic conditions decidedly different from those at any of the localities so far described.

Northeast of the Rarus group is a group called the War Eagle, belonging to Angus MacDougall. A large quantity of magnetite is exposed on the claims nearest the Rarus roup and is the principal metallic mineral to be seen, although the rocks contain also pyrite and chalcopyrite. The development work done on these claims consists of open cuts.

Southwest of the Rarus and adjoining it are the Berg claims, belonging to the North Midas Copper Co. The geologic conditions here are similar to those at the Rarus group. The rocks include altered limestone, greenstone, and intruded light-colored diorite porphyry. They are extremely altered and are much faulted. The rocks carry magnetite, pyrite, and chalcopyrite, but these minerals do not occur together in all the prospects.

Four tunnels have been started on the property, three of which were driven prior to 1916 and have a combined length of nearly 1,150 feet. The fourth tunnel was in progress in 1916, and at the time of visit in August was 80 feet long, but since that time has been extended. Tunnel No. 4 surprised the owners by yielding high values in gold, so that the work in this tunnel was continued with the idea of developing a gold rather than a copper mine.

CHOKOSNA RIVER.

Only one group of claims is held in the area between Kuskulana and Lakina rivers, the Kinney-Golden property, on Golden Creek, a tributary of Chokosna River. The group consists of seven claims strung along the contact of interbedded Triassic shale and limestone with Carboniferous (?) lava flows. Two parallel faults, about 500 feet apart, which strike east and dip south, have brought Triassic shale into contact with Nikolai greenstone and Chitistone limestone along one fault and with much older (probably Carboniferous) greenstone along the other. The geologic conditions are represented in figure 2.

A tunnel run at an elevation of approximately 4,200 feet was driven 200 feet through shale, Nikolai greenstone, and a light-colored porphyritic dike, into Chitistone limestone. The copper mineral is chalcopyrite and is best developed along the greenstone-limestone contact. In the claims farther east the limestone and greenstone disappear, leaving the two shale areas in contact, but copper is found along the southern fault contact, where several open cuts have been made.

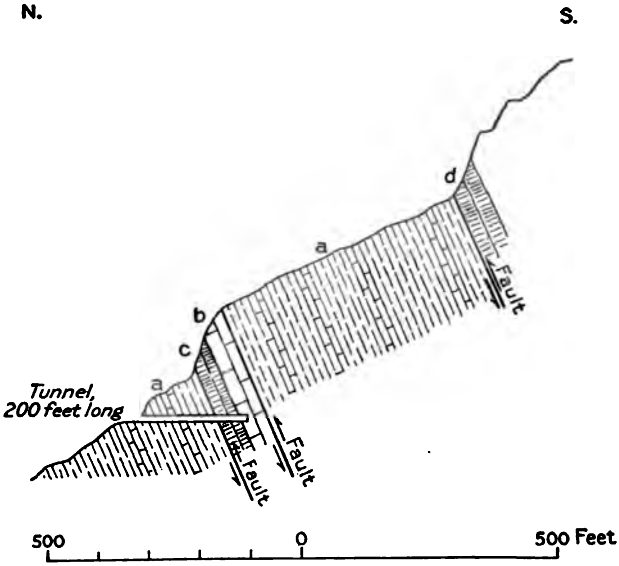

FIGURE 2.—Section showing geologic structure on Golden Creek. *a*, Shale and thin-bedded limestone (Upper Triassic); *b*, massive limestone, Chitistone (Upper Triassic); *c*, altered lava flows, Nikolai greenstone (Triassic?); *d*, altered lava flows, probably Carboniferous.

LAKINA RIVER.

The property of the so-called Lakina Copper Co. includes 36 claims at the head of Lakina River. Prospecting has been done on both sides of the river near the lower end of the glacier, but attention is now given chiefly to one claim west of the river. A tunnel is being driven in greenstone at an elevation of about 2,100 feet above the bars of the Lakina at the mouth of Mill Creek. When the property was visited, in September, the tunnel had been run to a length of 235 feet. It follows a well-defined shear zone that strikes N. 10° W. and dips about 70° W. The shear zone was traced northward up the mountain for nearly 1,000 feet vertically and apparently continues to the limestone on top of the mountain. It is exposed in open cuts and is marked by a leaching of the greenstone, caused by circulating waters. The ore in the tunnel, as exemplified by a hand specimen, seems to be all chalcocite but probably includes also bornite. Its gangue at some places consists of veins of coarse gray calcite, the largest 3 inches thick. At other places the chalcocite is accompanied by no gangue but occurs as veins in the greenstone or as grains disseminated through it. Most of the chalcocite, however, is found in veins along fracture planes. In the open cuts above the tunnel the copper mineral is bornite unaccompanied by chalcocite and in places is considerably oxidized. Several tons of ore was piled on the dumps awaiting shipment when the snow came.

The development work includes the tunnel and open cuts already mentioned and an excellent sled road leading from the Lakina at the mouth of Mill Creek to the tunnel. A wagon road follows Lakina River from Mill Creek to Long Lake on the Copper River & Northwestern Railway. This wagon road crosses the river by fords at several places and is not used at times of high water.

The property also includes several claims along the west side of Lakina River, where native copper occurs in greenstone in small veins, grains, and irregular bodies. Several small streams coming down from the mountain have cut deep gulches that lay bare the rock and expose the copper, which is scattered over the surface of the rock. No effort is now being made to exploit this copper.

In addition to mining claims the company holds a mill site on Mill Creek, where power for mining can be obtained with no great difficulty and in quantity sufficient for all needs.

KENNICOTT VALLEY.

A group of claims on Hidden Creek has been held for many years by the Tjosevig Bros. This property has recently changed ownership and is now being developed by the Josevig-Kennicott Corporation. The claims are on the south side of Hidden Creek along the contact of the Nikolai greenstone and Chitistone limestone. The chief copper mineral is bornite in stringers and irregularly shaped masses in greenstone. One of the chief obstacles to the development of this property has been the difficulty of transporting the ore to the railroad. Hidden Creek flows through a narrow valley that is shut in by precipitous walls and dammed across its mouth by Kennicott Glacier, which forms a lake that breaks out periodically when so much water has accumulated that the ice can no longer withstand its pressure. A flood of this kind in 1916 did much damage to the railroad at McCarthy. Mining supplies have been carried along the lateral moraine of the glacier and finally over the glacier itself to the northeast side of Hidden Creek, and any ore that may be shipped now must be hauled over the glacier in winter. The new company proposes to build a tram over the mountain south of Hidden Creek and down along the Kennicott Glacier.

Eleven copper claims at the head of the north branch of Fourth of July Creek are owned by Woodin & Herman. The copper deposits are in the greenstone just below the base of the massive limestone that caps the mountains at the head of the stream. They are made up of bornite and chalcopyrite, and are typical of the greenstone deposits generally. Ore was being sacked at the mine in September in the expectation of hauling it by sleds over Fourth of July Pass and down Lakina River to Long Lake for shipment on the railroad.

A small area of coal-bearing rocks near this copper property has been known for many years. Its extent has not been determined, but claims have been staked on it and the coal may be valuable for local use if the copper deposits at the head of Fourth of July Creek prove to be extensive.

A group of claims on the point of mountains between the forks of Kennicott Glacier is held by the Great Northern Development Co. The south end of the point is made of Nikolai greenstone, which is overlain by beds of massive Chitistone limestone dipping about 30° N. Development and assessment work has been done for a number of years on claims along the contact. A promising body of ore was struck in the summer of 1916, and a contract was let in September for driving a tunnel during the coming winter to explore the ore further. The tunnel is high on the mountain, over 2,000 feet above the glacier, and is reached by a long trail from the south end of the low hills at the glacier forks. Supplies for use on this property are brought to a point on the east side of Kennicott Glacier about 3 miles above Kennicott and are sledded or packed across the glacier. Good traveling is found on the glacier and a crossing can be made at almost any time, for the ice is smooth and without bad cracks.

KENNECOTT MINES.

The Kennecott-Bonanza mine shipped its first ore early in 1911. Since then the Jumbo mine has been opened, and exploratory work has been started on the Erie claim. These properties all lie within 3 miles of one another, along the contact of the Nikolai greenstone with the Chitistone limestone (Pl. XI) on the east side of Kennicott Glacier. They belong to the Kennecott Copper Corporation.

During the five years since 1911 a large quantity of high-grade copper ore has been shipped to the smelter from the Bonanza and Jumbo mines, and the mines themselves have been opened so as to expose the copper deposits and give a much more accurate idea of their extent and character than could be gained at the time when they were examined by Capps and the writer.[1] For this reason it seems desirable to describe these deposits more fully than the other deposits in the district, especially as such a description may be helpful to anyone who may be studying other copper deposits in the limestone. The writer acknowledges his indebtedness to those in charge of the mines for placing at his disposal every means for studying the copper deposits and in particular to Mr. H. D. Smith, Mr. E. T. Stannard, and Mr. A. M. Bateman for a great deal of information which a geologist who has not been closely associated with the work of exploration can not get readily, if at all. Although he had every facility for studying the ore deposits, the writer did not find it possible in the few days that were available for his work to do more than make a quick examination of the mine workings.

KENNECOTT-BONANZA MINE.

The Bonanza mine is in the mountains between Kennicott Glacier and McCarthy Creek, at an elevation of 6,000 feet (Pl. XI). The Jumbo mine is nearly a mile northwest of the Bonanza and a few hundred feet lower. The main tunnel of the Erie is 1¾ miles still farther northwest, at an elevation of 4,325 feet and within half a mile of the Kennicott Glacier.

The copper deposits of the Bonanza, the Jumbo, and the Erie resemble one another in the character of the ores and in the fact that they occur in the limestone only a short distance above the greenstone. It is therefore probable that they were formed at the same time and under the same conditions.

The Bonanza mine is on a sharp ridge that separates the heads of Bonanza and National creeks, tributaries of Kennicott Glacier. The head of National Creek valley is a glacial cirque; that of Bonanza Creek is also a cirque with a precipitous wall on the east, next to the mine. This cirque is still occupied by a small glacier. The ridge trends N. 30° E. From the mine the ridge rises steeply northward to the divide between Bonanza and National creeks and the basin of McCarthy Creek, but extends southward without much variation in elevation for half a mile and then drops off steeply

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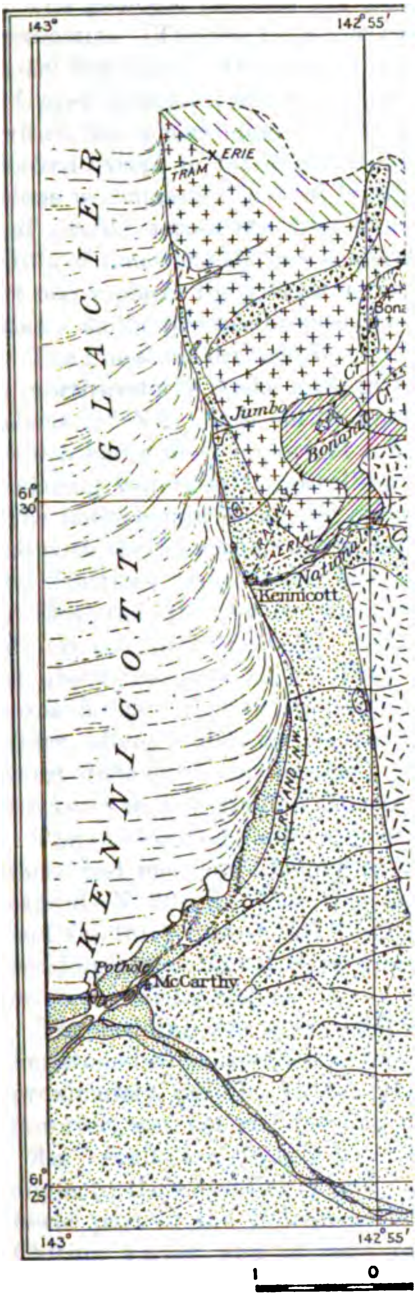
[1] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 84–92, 1911.



SKETCH MAP OF VICIN

toward Kennicott Glacier. A trail up National Creek leads to the mine.

The geologic features are simple. On the south is the Nikolai greenstone (Triassic ?), a succession of ancient lava flows at least 5,000 feet thick. It is overlain by the massive Chitistone limestone (Upper Triassic), but is separated from it by a thin bed of shale, which has a maximum thickness of only 4 feet and is easily overlooked except in favorable exposures, because the base of the limestone is commonly covered by débris from the cliffs above. A typical profile across the limestone-greenstone boundary shows steep cliffs of limestone above a moderate slope in the greenstone, although at many places the greenstone is hidden by loose material, or "slide rock," as the prospectors usually call it.

The limestone between Kennicott Glacier and McCarthy Creek has a northwesterly strike and, in the vicinity of Bonanza mine, dips about 22° NE. It is cut by numerous faults and fractures, some of which had a most important influence in directing the course of circulating waters and controlling the deposition of copper minerals. The faults comprise, among others, the two systems that had most to do with the formation of the deposits. One system is distinguished by fractures with steep dips and with approximately northeast strikes; the other by fractures with practically the same strike and dip as the limestone beds. Both fault systems probably originated at about the same time. They are intersected by steeply dipping cross faults, either of the same age as the major faults or possibly older, along which the copper-bearing solutions spread out for a short distance from the main fractures. They are also crossed by fractures that originated after the ore was deposited.

The ore-bearing faults and fissures of greatest importance among those just mentioned belong to a zone of fracture and faulting that extends N. 30° E. This zone is made up of steeply dipping faults and fractures that strike N. 30°-70° E. and that, together with the bedding-plane faults, were most effective in directing the flow of mineral-bearing waters.

The bedding plane or "flat" faults indicate movement of one limestone bed on another or movement along a plane parallel or approximately parallel to the planes of bedding. Such movement, however, was not restricted to planes of bedding, for in places the "flat" faults are slightly wavy and cross limestone beds at a slight angle to their bedding planes. Bedding-plane faults occur in the lower part of the Chitistone limestone at many places throughout Chitina Valley, and at least four are recognized in the Bonanza mine. The contact of limestone and greenstone in particular was a place of movement, which was facilitated, no doubt, by the thin bed of shale at that place. Evidences of such movement are found in the shale bed at Bonanza mine.

Two principal cross faults are seen in the Bonanza mine, the Mammoth, which strikes N. 52° W. and dips 70° N., and the Azure, which strikes N. 62° W., dips high north, and is in reality a shear zone about 100 feet wide, made up of minor nearly parallel faults. The Mammoth fault produced a displacement of less than 20 feet in the limestone beds and is older than the ore. (See p. 167.) The Azure fault is a normal fault that caused very little displacement. Movement has taken place along this fault since the ore was deposited, but the faulting may have begun earlier. Much of the limestone along the fault zone is crushed. The direction of latest movement in the Azure fault is indicated on slickensided surfaces by striae that dip 70° W.

Although the Mammoth and Azure faults are the most conspicuous of the cross faults in the Bonanza mine, many other cross faults having the same general strike cut the principal ore-bearing fissures. Some of them are manifestly later than the ore, for they offset it. Some of them carry small quantities of ore, as may be seen on the 400, 500, and 600-foot levels. It appears not improbable that cross faults were produced when the principal shear zone was formed and that movement took place along some of the faults of both sets after the ore was deposited.

It is difficult to make more than qualitative statements in regard to the displacements produced by faulting except as to a few of them. The vertical displacement along steeply dipping faults is slight. Some of the movement, particularly along faults that run north and south, was nearly horizontal, or parallel to the direction of the present dip. The displacement in this direction is small but greater than that in the direction perpendicular to the bedding planes. Displacement along the bedding planes is difficult to measure because reference points are lacking, but in some places not far distant from Bonanza and Jumbo mines it is considerable, amounting to hundreds of feet.

Close examination of the rocks adjacent to the contact between the Chitistone limestone and the Nikolai greenstone at the Bonanza mine disclosed the following section:

Section at Bonanza mine.

	Feet.
Limestone, magnesian, granular, ore-bearing.	
Fault; in places forms contact between magnesian and nonmagnesian limestone.	
Limestone, dark gray, nonmagnesian	50-60
Limestone, siliceous, containing a little pyrite	20
Shale, red or green	4
Greenstone, amygdaloidal (Nikolai).	

The first large ore bodies found were in the magnesian limestone, so that at one time it was supposed that this rock had controlled ore deposition, and exploratory work was conducted accordingly. As the work proceeded, however, this supposition had to be given up, for ore was found in both the magnesian and the nonmagnesian limestone. At some places a fault approximately parallel to the bedding planes separates the magnesian and nonmagnesian limestones, but at others the contact of the two is defined neither by a fault nor by a bedding plane but crosses the bedding planes irregularly.

The list of copper minerals in the ores of the Kennecott-Bonanza, formerly thought to include only chalcocite, covellite, and copper carbonates, has been extended as underground work proceeded and now includes chalcocite, covellite, azurite, malachite, enargite, bornite, chalcopyrite, bluestone or chalcanthite, and possibly other minerals. The ore is dominantly chalcocite. Covellite, like azurite and malachite, is common and, at least in some places, seems to be a product of the alteration of chalcocite. It forms veinlets that cut the chalcocite and it coats with tiny crystals the surfaces of open spaces in the chalcocite. Enargite is rare but is found in the 150-foot and 300-foot levels. Bornite is found throughout the mine and chalcopyrite in the lower levels, though it is uncommon.

The ore occurs as great tabular replacements of limestone along "vertical" faults, as tabular replacements along "flat" faults, as irregular-shaped masses, as networks in brecciated limestone veined with calcite, and as veins that have replaced limestone along bedding planes and that are in places only a few inches apart.

The great ore bodies belong primarily to the "vertical" fault system and have been found at the intersection of the "vertical" with the "flat" faults. They lie above the "flat" fault and terminate sharply against the underlying limestone, yet copper ore is found along "vertical" fissures below the "flat" faults at some places, as in the "little Bonanza" open cut at the south end of the ore body. The "little Bonanza" is a mass of chalcocite, covellite, copper carbonates, and chalcanthite in "vertical" fissures of the main fault system, which lies on the west side of the ridge and extends down to the shale. It was not exposed to view until the talus material had been cleared away.

The largest ore bodies so far uncovered were found at the south end of the mine. They followed fissures striking N. 50°–70° E. and were adjoined on the north by smaller bodies striking about N. 30° E. The formation of the larger deposits was much influenced by the Mammoth fault, for, although the limestone beds were not greatly displaced by the fault, the copper-bearing solutions spread out along it and produced local enlargements of the ore bodies. South of the fault the ore reached a width of about 80 feet, but a short distance north of it the width was much reduced. The Mammoth fault appears only in the upper levels, for it crosses the south end of the ore body and reaches the northeastward dipping surface of the greenstone between the 200 and 300 foot levels.

The "vertical" bodies of the higher levels had a high westerly dip, which increased in steepness as the ore was followed in depth toward the northeast. Ore was mined in the main fissure system to a width of 85 feet.

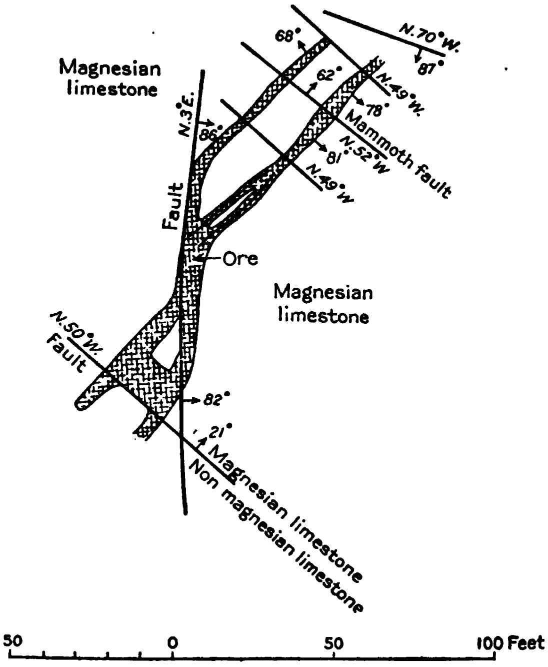


Figure 3.—Sketch showing displacement of ore body along a vertical fault, 100-foot level of Kennecott-Bonanza mine. From mine map.

The ore is cut by faults that show little displacement, at least not much is shown by the steeply dipping faults. The Azure fault is over 800 feet northeast of the Mammoth fault. It appears in the 300 to 600 foot levels and meets the greenstone between the 600 and 700 foot levels. Movement took place in it after the ore was formed. Three other principal "vertical" north-south faults offset the ore bodies, as is evident at the surface and in the 100-foot level of the mine. Such faulting as that indicated in figure 3, however, apparently took place before the ore was deposited and offset the two earlier faults, which the ore-bearing solutions followed later.

The north-south fault caused displacement chiefly in a horizontal direction. One of the striking features of the ore deposits is the sharpness with which they are limited by some of the fault planes. In many places a thin gouge, scarcely thicker than a sheet of paper, has been sufficient to prevent the solutions from reaching the limestone on one side of the fracture while that on the other was being entirely replaced. The gouge along the fault planes is locally highly colored with iron oxide.

The exposures at the surface of the Bonanza mine show no more oxidized ore than those in some of the lower levels. Oxidized ore continues to the lowest (700-foot) level and is evidently most abundant where the ore was faulted and crushed and where water could therefore circulate freely. Oxidation is at some places confined to one side of a tight fault. Locally the chalcocite is brecciated and much oxidized, showing kernels of original chalcocite in oxidized ore. The Bonanza is at present a dry mine.

The mine workings have now reached the 700-foot level. The main or adit level is the 150-foot level. From the adit level an incline runs nearly parallel to the contact of limestone and greenstone and descends to the 600-foot level. From the incline, in turn, levels are driven off northeastward into the ore body. A winze has been driven from the 600-foot level to the 700-foot level. The 300-foot level connects by a short raise with the McCarthy Creek side of the ridge. Much high-grade ore, including most of that exposed originally at the surface, has been mined above the adit level, through which it has been drawn off. In this mine thorough exploration is necessary to trace the ore; all small veins and stringers must be closely followed, for many of them develop into valuable bodies of ore within short distances.

JUMBO MINE.

The copper deposits of the Jumbo mine resemble in most respects those of the Bonanza. The mine is in the Chitistone limestone, near the head of Jumbo Creek, just above the contact of the Chitistone with the underlying greenstone. Jumbo Creek originates in a small glacier on the west side of Bonanza Peak and flows southwestward to Kennicott Glacier, which it joins 1¼ miles north of Kennicott. The glacier is confined on the north and east and for some distance on the south by precipitous cliffs of limestone. The Jumbo mine is in the north wall of this cirque, nearly half a mile from the head of the glacier. All the mine buildings are set on the glacier.

The geology of the mine is practically the same as that of the Bonanza. A stratigraphic section shows greenstone at the base overlain by 2 feet of shale. Then come, in ascending order, about 20 feet of siliceous limestone containing a little pyrite, 50 to 60 feet of dark-gray limestone, and finally granular magnesian limestone. In the adit or 180-foot level of the mine the limestone beds strike N. 50° W. and dip 34° N. The dip is therefore a little greater than at the Bonanza and the strike is a little more westerly. A short distance east of the entrance of the 100-foot level of the Jumbo a light-colored porphyritic dike 2 feet thick intrudes the limestone. It has not yet been encountered underground.

A fault zone whose general course is a little south of northeast cuts the limestone but displaces the beds very slightly. It comprises fissures and minor faults that range in strike from N. 60° E. to east and a few that strike about N. 30° E. This fault zone is made up of the principal ore-bearing fissures. Near the outcrop of the ore the dip of these fissures is 70°–80° W., but as the fissures are followed to the northeast the dips become steeper and in some of the faults are southeast.

The main fissure zone is cut by cross faults that trend north-northwest and by a few that trend north. At one locality the ore is displaced 1 foot by a fault that trends north and at another place 2 feet by a fault that trends north-northwest.

Of much more importance than these cross faults are the bedding-plane or "flat" faults. In the Jumbo mine, as in the Bonanza, the bed of shale between the limestone and the greenstone is evidently a plane of movement, for wherever the shale is exposed it is crushed to a thick gouge. The fault along the shale bed has apparently a much less significant relation to the copper deposits than the fault immediately below the rich ore bodies. This fault is about 80 feet above the greenstone and is in places made up of several closely spaced parallel faults. It does not strictly follow the bedding planes but crosses the bedding at a slight angle, and on the 500-foot level it strikes N. 70° W. and dips 35° N. It is cut by all the levels and marks the bases of the rich ore bodies. Movement along this fault plane after the ore was deposited is indicated on the 180-foot level by a fault breccia containing a little chalcocite. Although this postmineral movement has taken place, the original displacement occurred before the ore was deposited.

The ore of Jumbo mine is prevailingly chalcocite, but includes a subordinate quantity of copper carbonates, as well as enargite, bornite, and chalcopyrite. In places covellite is associated with the chalcocite. According to Mr. H. D. Smith, in charge of the mining, if the proportion of chalcocite and carbonates that can be distinguished by the eye is estimated as 98 per cent, then 1.9 per cent will represent the covellite and 0.1 per cent the bornite and chalcopyrite. This estimate is, of course, only approximate, but it indicates the relative quantities of the copper minerals in the ore. The ore from the Jumbo mine shows more oxidation than that from the Bonanza. The carbonate ore consists generally of malachite and azurite, but that in certain stopes includes malachite alone. Silver occurs with the copper at the Jumbo mine as well as at the Bonanza. The proportion is slightly variable and ranges from 14 to 16 ounces to the ton of high-grade ore. The silver content of chalcocite near fissures is less than that found at a distance from them, a fact demonstrated by careful assaying. The width of the ore-bearing ground worked is not less than 240 feet, yet the limits of the ore have not yet been reached.

In form the ore bodies are like those of the Bonanza. The large tabular masses of chalcocite replace limestone along the northeasterly striking faults, but all openings in the fractured limestone along the fault zone were invaded by the ore-bearing solutions so that stockworks and irregularly shaped bodies are common.

Ore was deposited in great quantities at the intersection of the "vertical" and bedding-plane faults between the 400 and 600 foot levels. The "vertical" faults here strike N. 65° E. and dip steeply to the northwest. The bedding-plane fault strikes N. 72° W. and dips 34° N. The great ore body was on the southeast side of the main "vertical" fault and lay for the most part, but not entirely, above the bedding-plane fault, between it and the magnesian limestone. It extended from a point a short distance above the 600-foot level to a point 30 feet above the 400-foot level. In projection on a horizontal plane it had a length of 400 feet. At its lower end was an open cave in the limestone, partly below and partly above the fault. A horizontal section of the ore body at the 500-foot level is shown in figure 4.

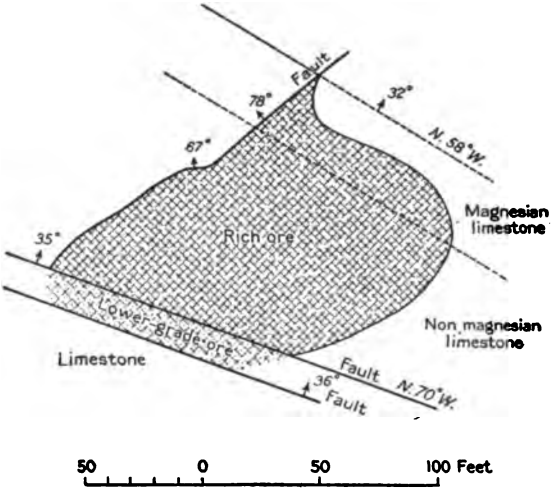


FIGURE 4.—Horizontal section of the ore body in the Jumbo mine on the 500-foot level. From mine map, slightly modified.

This great mass of ore was practically solid chalcocite, with which was mixed an almost insignificant quantity of included limestone, largely altered to residual clay. It yielded 50,000 tons of copper ore, much of which ran 76 per cent copper. This massive body of chalcocite was at the 500-foot level, bounded on its lower side by a bedding fault, but below this fault there was ore of lower grade which was terminated, 6 to 8 feet lower, by a second fault parallel to the first, beneath which no ore was seen except a few tons at one place.

A map of the 500-foot level shows, in addition to the ore body just described, two principal tabular ore bodies along parallel "vertical" fractures extending northeastward and other irregular-shaped bodies. On the 700-foot level also there were two main fissures at the northeast extension of the drifts. The sharp, clean-cut boundaries between limestone and chalcocite and the total absence of gangue minerals except calcite are striking features of the ore deposits both here and at the Bonanza.

The main adit of the Jumbo mine is the 180-foot level. This level penetrates between 200 and 300 feet of greenstone before entering the limestone. From this level an incline with a slope of 33° to 34° descends to the 700-foot level, in which a shaft is being sunk. The incline was started with the expectation that it would penetrate barren ground away from the ore body, but it encountered much high-grade ore. Intermediate levels were driven to the northeast from the incline into the ore bodies, just as they were at the Bonanza.

ERIE CLAIM.

The Erie claim is a little more than 3½ miles north of Kennicott and less than half a mile from the glacier. Three prospecting tunnels have been started on the claim. The principal tunnel was run on the largest showing of ore, 1,575 feet above the glacier, at an elevation of 4,325 feet. It is driven in limestone at the contact of the limestone and greenstone. The boundary between these formations in this vicinity runs nearly northwest, following the base of a limestone wall that rises above steep slopes in the greenstone. The steepness of the slopes and the absence of talus in many places give unusual opportunities for examining the shale between the limestone and the greenstone. The shale gives clear evidence of movement along the bedding and in places shows copper staining. Another tunnel, on which considerable work has been done, is 215 feet lower and a short distance to the west. A short tunnel, on which little work has been done, is about 100 feet lower and still a little farther northwest. All three tunnels are in limestone just above the limestone-greenstone contact.

The geologic structure at the Erie mine differs from that at the Bonanza and Jumbo mines chiefly in the faulting, which has here apparently been more pronounced and less restricted to narrow zones. A number of displacements by faults that cross the contact were seen, and at one place a wedge-shaped mass of limestone and greenstone had been thrust up into the limestone nearly 20 feet without disturbing the parallelism of contact and bedding planes. A wide area of the limestone is cut by minor fractures in which copper minerals were deposited.

All the copper minerals seen at the Bonanza and Jumbo mines are found in the Erie—chalcocite, covellite, enargite, bornite, chalcopyrite, and carbonates. The Erie ore so far uncovered is much more oxidized than that of the Bonanza and Jumbo mines.

The middle tunnel was started on a vein of carbonate ore along an east-west fault having a southerly dip. It was driven eastward for a short distance till it encountered a small light-colored dike striking N. 22° W. The dike cuts the ore and was itself fractured and slightly displaced by later movement along an ore-bearing fault which strikes N. 35° E. and has a steep easterly dip. This fault or others approximately parallel to it was followed northward in order to reach the magnesian limestone, then supposed to be the copper-bearing rock. At 400 feet from the mouth of the tunnel a crosscut was driven. The fissures of the main fault system carry copper minerals, but not in sufficient quantity to give much encouragement for mining. They are cut by eastward-trending faults, some of which, like that at the mouth of the tunnel, carry copper. At least one well-defined bedding fault was encountered. No alteration of the limestone near the dike was noticed, and in fact alteration near small dikes in this district is unusual, although local enlargements of the dikes have produced decided alteration of the limestone in places at the head of Lakina River.

About 30 feet south-southwest of the mouth of the tunnel is an incline, 40 feet deep, sunk in limestone along the plane of a fault that brings greenstone and limestone into contact. The fault strikes N. 30° E. and dips approximately 60° E. It is a normal fault, for the greenstone lies on its west side. A small quantity of good high-grade copper ore was taken from the incline.

The upper, larger tunnel extends in general east-northeast, the principal direction of fissuring, but is somewhat winding, for it followed the ore, which is not confined to a single fissure and is besides here offset by cross faults. Fracturing is pronounced and the ore is distributed irregularly. Two cross faults have produced displacements of 15 and 20 feet in the main ore fissure. Some of the cross faults carry copper minerals in small amount.

At the time of visit this tunnel has been extended about 700 feet and two shafts had been started in it. These shafts are steeply inclined, following the plane of a fault or faults that dip 70° to 80° S. The shallower of the shafts, that nearer the tunnel mouth, is about 40 feet deep and shows a displacement of the beds but has not been sunk deep enough to determine the amount of the displacement. The second shaft is about 65 feet deep and shows that the beds on the hanging wall side have moved upward, relatively, a distance of 20 feet. A sublevel about 200 feet long was being driven from the bottom of the deeper shaft. It follows ore-bearing fissures, but the fissures make a slight angle with the fault that displaces the limestone and greenstone, and thus in going eastward the tunnel is gradually separated from the fault. Considerable high-grade ore was encountered along the sublevel.

The Erie ground has been more shattered than that at the Bonanza and Jumbo mines. The displacement by faults is greater, and the migration of copper-bearing solutions through the country rock is greater, at least on the surface exposures.

North of the camp, near and somewhat above the lower tunnel, is a small gulch which is separated from the camp by high limestone cliffs and a small ridge. The southern side of the gulch is a dip slope, the northern side a limestone scarp or wall. The surface of the beds on the south side shows a network of calcite veinlets that have filled fractures in the crushed limestone. Associated with these veinlets of calcite are veinlets of chalcocite, some of them no thicker than paper, in which the chalcocite has been in large part altered to azurite. The limestone is intruded by a dike about 2 feet thick, which has the same dip as the slope of the scarp on the north side of the gulch and in places forms the face of the scarp. The limestone is also cut by northward-trending vertical faults, along which it is darker and much harder or more resistant to weathering than the unaltered rock, so that the veins of calcite in the fault and in the limestone adjacent to it for a width of a foot or more stand out in relief. Several such faults, from 10 to 20 feet apart, were seen. They indicate slight movement in the limestone and carry chalcocite, mostly altered to azurite. Similar copper veins were seen in the bedding planes of the limestone. The whole mass makes an ore that may perhaps be mined profitably.

The Erie claim is equipped with an aerial tram, 2,700 feet long, run between the lateral moraine of Kennicott Glacier and the upper tunnel. A trail leads from the lower end of the tram to Kennicott. A quantity of high-grade ore, mined from the tunnels, was ready for shipment as soon as snow should make sledding possible.

Ore from the Bonanza and Jumbo mines is brought to the mill by aerial trams. The tram to the Bonanza mine is 2.8 miles long and has one angle station. That to the Jumbo mine is almost 3 miles long and leads directly from the mine to the mill. These two trams together have a capacity of over 800 tons daily.

Most of the ore shipped from Kennicott is of high grade and requires no concentration. Part of it, however, is concentrated in the mill, the tailings from which are treated in the leaching plant with ammonia, which dissolves out the copper carbonates. By this means 65 to 72 per cent of their content of copper is recovered from tailings that carry from 1.5 to 2 per cent of copper. The loss is probably due to the fact that fine particles of chalcocite are not affected by the ammonia. Much experimental work has been and is being done to perfect the leaching plant. The difficulties encountered have been mechanical rather than chemical, chief among them being the difficulty of removing the precipitate from the still.

The shipments of ore from Kennicott in August, 1916, amounted to 8,500 tons. During the same month 800 tons of ore was concentrated in the mill and 80 tons of fines was treated in the leaching plant. It was planned to run the mine at full capacity through the coming winter and to mill about 750 tons of ore a day. Full production has not been maintained in winter during preceding years, chiefly because of the lack of water and the difficulty of disposing of tailings before they have frozen.

MOTHER LODE MINE.

For several years the Mother Lode Co. has done development work on claims on McCarthy Creek, northeast of the Kennecott-Bonanza mine, and since 1913 has made shipments of ore each winter. The ore is chiefly chalcocite but contains a large proportion of covellite, azurite, and malachite, derived by oxidation from the chalcocite. It occurs along a shear zone that cuts the Chitistone limestone and strikes N. 30° E. Besides copper, the ore carries silver in the ratio of 1 ounce of silver to each 4 per cent of copper.

The deposits so far exposed are high above the limestone-greenstone contact, and in this respect differ from the ore bodies of the Bonanza and Jumbo mines, which are near the contact. A second point of difference is the much greater proportion of oxidized ore in the Mother Lode deposits.

Nearly 7,000 feet of tunnel, shaft, and raise have been driven in the ore body since the mine was opened, and as a result of the present season's work 14 carloads of ore were awaiting shipment in September when the mine was visited. This ore is hauled to the railroad after McCarthy Creek freezes and snow for sledding has fallen.

The mine is equipped with an aerial tramway having a length of slightly more than 5,000 feet and a difference in elevation between the loading and landing stations of about 2,500 feet. Its capacity is 300 tons a day. A suitable site for the loading station was not found on the solid rock and one on the glacier was therefore chosen. Although built on an apparently insecure foundation it has given satisfaction.

Plans are under consideration for enlarging and bettering the equipment. It is proposed to build a road down McCarthy Creek to connect the mine with the railroad and to erect a hydroelectric plant and mill for treating the ore. A site for the power plant has been chosen on McCarthy Creek, 2 miles below the landing station. Water for milling ore can be obtained from Diamond Creek, half a mile above the camp. About 40 men were employed on the property in the summer of 1916.

DAN CREEK.

The Westover group is on Boulder Creek, a tributary of Dan Creek. It is the property of the Alaska United Exploration Co. and is one of four groups on Boulder and Dan creeks that belong to the same company, which, although it is not a mining company, its business being to discover and sell prospects, has done considerable development work on Westover claim No. 1, on Golden Eagle claim No. 1, and on the Snow Bird groups.

The four Westover claims are on the east side of Boulder Creek, 2 miles above its mouth. They extend along the limestone-greenstone contact and cover an exceedingly rugged area. The Westover tunnel is at the base of a precipitous limestone cliff a few feet above the greenstone. It is 375 feet above the glacier from which Boulder Creek rises and 3,500 feet above Nizina River.

The ore is bornite, chalcocite, and chalcopyrite, the bornite predominating. The work thus far done shows that the ore is practically confined to two beds of limestone about 11 feet thick, which lie a few feet above the thin bed of shale that separates the limestone from the greenstone.

The original surface exposure showed a rudely wedge-shaped face of ore 35 feet long and about 10 feet high at its south end, where it consisted of massive bornite and chalcocite and where it was cut off abruptly from the limestone to the south. The north end, however, showed a gradation from bornite and chalcocite to silicified limestone. Underground work has revealed two principal ore bodies, one of which is exposed at the surface and extends in, as shown by the tunnel, for 35 feet; the other lies about 35 feet farther in from the boundary of the first body.

The copper minerals have replaced limestone along irregularly distributed fissures, which in the short time available for study could not be correlated with any system of faulting. Good evidence for faulting parallel to the bedding, however, was found, both along the shale bed between the limestone and greenstone and along bedding planes in the limestone. This faulting possibly accounts for the fact that the copper minerals are almost restricted to the two beds of limestone already mentioned, although the exact way in which they could be so restricted was not determined. However this may be, the ore is cut off sharply along the bedding planes.

The underground workings of the Westover, which, in addition to drifts and crosscuts, include three raises and four winzes, measure in all about 900 feet. The winzes range in depth from 5 to 60 feet. One of the raises was put up 73 feet.

About 100 feet above the Westover tunnel is a short tunnel and a shaft in a zone of crushed limestone that trends northeastward. Copper stains the limestone, but no ore body had been uncovered at the time of visit.

A considerable quantity of ore has been mined at the Westover and awaits shipment. Some of it was piled near the mouth of the tunnel and the rest was stored in crosscuts underground. A plan was under consideration for shipping the ore mined and other ore blocked out, and a proposal was made to erect a small cable tram between the tunnel and the glacier moraine, where the ore could be loaded on sleds and hauled away in winter.

Exploratory work on the Snow Bird group is represented by two short tunnels run in copper-bearing greenstone. This group comprises four claims, and is on the west side of Boulder Creek valley, opposite the Westover tunnel. The tunnels are a few hundred feet below the limestone-greenstone contact, but the claims extend to the contact and one overlaps it. Chalcocite is the copper mineral. It is disseminated in small grains through an irregular-shaped mass of greenstone which has been leached by circulating water and has taken on a lighter color than the surrounding country rock. Probably this leached portion of the greenstone is in a zone of fracture, but, if so, the trend of the zone was not determined; neither was the extent of the mineralized rock determined, for much of the rock surface is covered by talus.

GOLD LODES IN THE TIEKEL DISTRICT.

GENERAL CONDITIONS.

The success of the Cliff mine at Valdez and the discovery of many smaller gold-bearing quartz veins in that vinicity in 1910 stimulated prospecting in the mountains along the Valdez-Fairbanks road and led to the finding of several similar gold-bearing veins, most of which are in the vicinity of Tiekel (Pl. X, p. 156). None of these veins have yet proved to be of value as gold producers, but development work has been done on some of them, which may be regarded as promising prospects. Among such prospects are the claims belonging to Fred Reis, about 3 miles south of Tiekel Road House; the Portland group, somewhat nearer Tiekel and high on the mountain on the west side of the valley; the two properties commonly known as the Ross and Meckem properties, on Boulder Creek; the Telluride and Quail groups, on Hurtle Creek; and the property of the Quartz Creek Gold Mining Co., near the head of Quartz Creek. In this connection also the gold placers of Fall Creek may be mentioned. All these properties except the first two were visited by the writer in July, 1916.

The rocks in the vicinity of Tiekel are slate and graywacke, which, however, are locally so much altered that the term "schist" describes them better, particularly the slate. They are closely folded and in general strike a little north of west. In places the slate or schist is highly siliceous, consisting of alternating bands of quartz and slate of the thickness of a knife blade. The slates and graywackes are cut by numerous light-colored dikes of diorite porphyry and contain stringers, lenses, and well-defined veins of quartz. Some of the quartz veins are metalliferous and carry arsenopyrite, galena, and, in places, free gold. They are the veins that give promise of becoming gold producers.

The veins and the dikes of diorite porphyry were probably formed at the same time, although, so far as the writer knows, the dikes are not mineralized. Some of the small gold-bearing veins and lenses contain much gold, but, as a rule, the deposits are too small to make profitable mines. The problem of the district seems to be to find a vein large enough to mine or to find small veins spaced closely enough to pay for the dead work that must be done in mining them. This, however, may be said to be the problem of the prospector in most districts.

BOULDER CREEK.

Boulder Creek is a western tributary of Tiekel (Kanata) River, which it joins just north of the Tiekel Road House. Its two branches head in the same group of mountains in which the Valdez Glacier originates, are fed largely by melting snow and ice, and join at a point between 2 and 3 miles above its mouth. One of these branches comes from the south and the other, the larger branch, from the southwest. The valley of Boulder Creek is a hanging valley; its mouth is considerably higher than the floor of Tiekel Valley. A trail suitable for pack horses leads from Tiekel Valley around the canyon in which the lower part of the creek flows, and by a series of "switchbacks" gains the level of the old valley floor, from which either branch of the creek can be ascended without difficulty.

The Ross property is near the top of the ridge that stands between the south fork of Boulder Creek and Tiekel River. It is at an elevation of about 4,500 feet and is reached by a steep trail. The gold-bearing vein is in black siliceous slate, very much crumpled and sheared. A tunnel about 200 feet long has been driven on the vein but was closed at the time the property was visited. The vein is made up of quartz, arsenopyrite, and galena, and yielded very high assays in gold but is reported to be decidedly "bunchy."

The Meckem property is on the right branch of Boulder Creek, between 2 and 3 miles above the forks, and is easily accessible from the valley of Boulder Creek. The country rock is slate or schist and graywacke, striking east and dipping south. It is broken by joints that strike N. 20 W. and dip steeply to the west. These joints are parallel to a number of quartz veins and to a dike of diorite porphyry that is exposed about 100 feet east of the tunnel by which the property is being prospected. This tunnel is 150 feet above the creek and is about 75 feet long. It is driven in crumpled slate and graywacke. Above the tunnel are a number of lenticular branching quartz veins, the largest 8 feet thick in its thickest part. None of them was traced on the surface for more than 100 feet. Most of these veins are composed of white and massive "bull quartz," but the smaller veins are more or less cavernous and are stained with iron oxide. Unoxidized parts of the veins show arsenopyrite and galena.

QUARTZ CREEK.

Quartz Creek is a tributary of Tonsina River. It heads in a low, divide 4 miles from the Valdez-Fairbanks road and flows northwestward for 10 miles, joining Tonsina River a short distance below the outlet of Tonsina Lake. Quartz Creek has two principal tributaries, Bear Creek and Rainbow Creek. Bear Creek, the larger of the two, enters it from the south about 3 miles above the mouth of Quartz Creek. Rainbow Creek comes in from the east a mile above Bear Creek. Nearly all of Quartz Creek south of Rainbow Creek is above timber line. A good trail, dry but rather steep, leads from the Valdez-Fairbanks road at mile 55 to a broad pass at the head of Quartz Creek.

The rocks exposed in the upper part of Quartz Creek valley are slate, schist, and graywacke. The schist is highly siliceous and much crumpled. Its principal exposure is in the ridge between upper Quartz Creek and Hurtle Creek. The higher parts of the mountains northeast of Quartz Creek below Rainbow Creek are made up of black slate, altered dioritic rocks, and light bluish-gray crystalline limestone. These rocks are probably older than those that are exposed farther up Quartz Creek and are believed to be, at least in part, of Carboniferous age.

Quartz Creek was the scene of considerable mining in 1898 and 1899. Placer gold was found in the stream gravels and a small settlement sprang up at the mouth of Bear Creek, where the old cabins still stand. The gold-bearing gravels, however, were quickly mined out, and the promise of a new camp was not realized.

The property of the Quartz Creek Gold Mining Co. is about 2 miles below the head of Quartz Creek on the ridge between Quartz and Hurtle creeks. It comprises 37 recorded claims and includes a mill site. A large number of mineralized quartz veins crop out. Some of these veins are here designated by numbers that have been assigned to them by the owners. The claims have been prospected by two tunnels—one 175 feet long, driven to cut vein No. 3, the other 65 feet long on vein No. 2. The longer tunnel is at an elevation of approximately 4,800 feet. It is driven in black crumbled schist and finely banded quartz and graywacke. These sedimentary rocks are cut by numerous dikes of diorite porphyry.

Vein No. 3 crops out at a vertical distance of a little more than 100 feet above the tunnel. It strikes N. 40° W. and dips steeply to the east. It ranges from 1 to 2 feet in thickness and can be traced at least 400 feet. It is highly stained with iron oxide. The tunnel is not long enough to reach the vein, so that the character of the mineralization below the outcrop is not known. Vein No. 1, on the top of the ridge, contains arsenopyrite, galena, and chalcopyrite, or copper-bearing pyrite. The mineralization is typical of the district. Work on the tunnels had been discontinued at the time of visit, and the properties were attached for debts. Unfortunately the work done gives no better idea of the mineralization than can be gained from a study of the surface outcrops.

HURTLE CREEK.

Hurtle Creek is a small stream which flows into the upper or south end of Tonsina Lake. It is formed by the union of two branches, which come together about 2 miles from the lake. The west branch is about 5 miles long and flows almost due north, the east branch is somewhat longer and flows first north and then northwest. The valleys of both branches are above timber line, but spruce extends up the lower part of the creek to the forks. Both branches head against Boulder Creek, the east branch being separated from that stream by a comparatively low divide. Between the east branch and the upper part of Quartz Creek is a narrow ridge, which, at an elevation of about 4,500 feet, is crossed by a trail that leads to the Valdez-Fairbanks road at mile 55. The west branch rises in several small glaciers that lie in cirques at the south end of the valley.

The country rock of Hurtle Creek includes schist or slate and graywacke of the Valdez group, and is cut by numerous dikes of light-gray fine-grained diorite porphyry, whose courses are plainly seen on the steep rock walls of the valleys.

Two groups of claims have been staked on gold-bearing quartz veins on the east side of the west branch of Hurtle Creek, and at the time of visit, in July, 1916, were being developed by Messrs. Peter Layton and Charles Nelson, who, with one or two others, are the owners. One of these groups, the Quail group, is about 2 miles from the forks of Hurtle Creek, at an elevation of 4,000 feet, and includes 10 claims. The other is called the Telluride group, and includes 9 claims. It is higher on the mountain side than the Quail group and somewhat farther up the creek.

The veins of the Quail group have the better showing of ore and have been most developed. The country rock at the workings is gray slate or schist, which is much folded and sheared and cut by closely spaced northward trending joints that dip to the east. The deposits appear to lie in a fault zone of pressure and fracture. Some of the northward-trending fractures have been filled with mineralized quartz veins, and at least four veins have been uncovered. The largest vein strikes north and dips 60° E. It ranges in thickness from 10 to 18 inches, and contains arsenopyrite, galena, and free gold in a gangue of quartz. Four feet below it is a parallel vein, 10 inches thick, and 1 foot above it is another vein, somewhat thinner. The fourth vein is 25 feet above the main vein and ranges in thickness from 1 foot to 15 inches. Its dip is a little steeper than that of the veins below. This vein contains the same minerals but a larger proportion of free gold. Open cuts on the veins have exposed them for about 300 feet along the strike. The veins appear to be cut off or offset on the north by a light-colored dike of diorite porphyry, which strikes east and dips south. This dike is exposed on the south side of a small creek about 500 feet north of the workings. In addition to the open cuts along the veins, a shaft, 10 feet deep, was sunk on the upper vein, and a tunnel was started below to crosscut the veins. This tunnel, which had been run 25 feet at the time the property was visited, will have to be driven 70 or 75 feet to reach the lower vein.

Nearly 3 tons of ore was packed out on horses to the Valdez-Fairbanks road in 1914 and shipped to the Tacoma smelter. At the time the property was visited an arrastre, to be driven by water power, had just been completed but had not been put into operation.

FALL CREEK.

Fall Creek, which is about 7 miles long, joins Tiekel River 2½ miles northeast of the Tiekel telegraph station. Its general course is northward. For most of its length it occupies a narrow glaciated valley, from which it issues through a deep canyon and flows for a mile across the level gravel-covered floor of the Tiekel. Most of the stream is below timber line. The country rock along it is slate and graywacke.

Fall Creek was prospected by the earliest gold seekers who ventured into this region in 1898 and 1899 and again during the gold-quartz excitement, about 1910, but its gravels did not prove profitable, and when the creek was visited in July, 1916, only three men were working along it.

A number of gold-bearing quartz veins have been staked in the valley, but only the placer gravels were receiving attention. Ten or a dozen placer claims have been staked. The two claims on which work was being done were visited, yet at both only preparatory work was in progress; no mining had yet been done.

Messrs. Nick Meckem and Fred Reis were preparing to sluice gravel on the upper end of claim No. 5, which is in the canyon at a place where the gravel deposits are shallow and are confined to points inside the bends of the stream. The gravel-covered point where work had been started measures only about 50 by 100 feet and the deposit is 6 to 8 feet deep. A channel had been made on the east side of the creek next to the canyon wall and sluice boxes were being set up to wash the 2 feet of gravel that remained after the boulders has been cleared away. The gravel is slate and graywacke and includes a large number of boulders of graywacke, many of which have to be broken by powder in order to get them out of the cut. The gold is not distributed through the gravel but is found only on bedrock, the upper few inches of which have to be taken up. It is heavy and considerably worn.

On claim No. 10 Jack Reynolds was mining the low bench that borders the creek. The channel is wider here than below, for the claim is above the canyon, in the open valley, at an elevation of only about 2,400 feet, well below timber line. Here, along the east side of a bend in the creek, there is a low bench of gravel, 6 to 7 feet thick, through which Mr. Reynolds had run a line of sluice boxes about 200 feet long. The gravel consists largely of boulders of graywacke, many of which have to be broken by powder, and when this and other coarse material had been taken out about 2 feet of finer material remained that could be shoveled into the boxes. The gold here, like that mined farther down the creek, is heavy and rounded and is found only on the bedrock. Mr. Reynolds reported that with a rocker he took $21 from a bar in five hours, but that he did not regard the bar as pay ground.

MINING ON PRINCE WILLIAM SOUND.

By Bertrand L. Johnson.

GENERAL FEATURES.

The mineralization of the closely folded rock beds that border Prince William Sound introduced into them a considerable variety of minerals, among which were gold, silver, chalcopyrite, chalmersite, pyrite, pyrrhotite, arsenopyrite, galena, sphalerite, stibnite, quartz, epidote, albite, chlorite, calcite, and ankerite. The valuable metals of the ores of this region are copper, gold, and silver. The gold thus far observed is native. The copper occurs chiefly as chalcopyrite, but another copper-iron sulphide (chalmersite), containing about 23½ per cent of copper, has been recognized at prospects on Landlocked Bay and on Knight Island. Silver has been noted as an alloy of the native gold and is also associated with some of the copper ores, but in what combinations is not known.

The ore deposits of this region may be broadly grouped into two classes—copper deposits and gold-bearing quartz lodes. The mineral associations in both gold and copper deposits are in general the same, the dominant characteristics of the deposits depending on the relative abundance of the different minerals. The copper mines produce large quantities of gold or silver, or both, and the gold-quartz lodes contain small quantities of chalcopyrite. The gold-quartz lodes occur in the folded and broken graywackes and argillites; the sulphide ores are restricted to the sheared slates, graywackes, limestones, and greenstones. The gold districts lie in a belt that parallels the shore of the sound and nearly surrounds the belt which contains the copper districts, to the south.

The gold-quartz ores are free-milling. They are crushed locally in small stamp or roller mills and the concentrates are shipped to the smelter at Tacoma, Wash. The copper ores are base and require smelting, with or without previous concentration. At one plant a flotation process is in operation. No local smelters being available, the copper ores are shipped to smelters at Tacoma, Wash., and Anyox, British Columbia, where their copper, gold, and silver content is recovered.

The productive mines on Prince William Sound in 1916, so far as known, included 8 copper mines and 10 gold mines. As usual, a much larger quantity of copper ore than of gold quartz was mined and treated, and the total value of the metals obtained from the copper ores was several times that of the metals from the gold quartz ores. The value of the total mineral output of the Prince William Sound region in 1916 was $2,975,200, compared with $1,340,996 in 1915.

COPPER MINING.

GENERAL CONDITIONS.

Copper mining in the Prince William Sound region showed a greater activity in 1916 than in the preceding year, and this activity would probably have been much more noticeable had it been possible for the owners of small copper mines to take advantage of the high price of copper and to sell their ore on more favorable terms than were obtainable at the customs smelters, which throughout the year were operating to their full capacity. Both of the regular producers, the Kennecott Copper Corporation, at Latouche, and the Ellamar Mining Co., at Ellamar, made large shipments as usual. The Granby, Consolidated Mining, Smelting & Power Co. (Ltd.), owner of the Midas mine, in the Valdez district; the Alaska Mines Corporation, controlling the Schlosser property, on Port Fidalgo; the Dickey Copper Co., on Port Fidalgo; and the Fidalgo Mining Co., on Port Fidalgo, also shipped considerable ore. Small shipments were made from the Buckeye group, on Landlocked Bay, and from the Copper Coin group, on Knight Island. The Threeman Mining Co., on Landlocked Bay, which had shipped much ore in previous years, made no shipments in 1916. Development work was done on some of the nonproducing properties, and assessment work is reported on many others. Crude ore was shipped from all the producing properties, and in addition copper-bearing flotation concentrates were shipped from the Beatson Bonanza mine, on Latouche Island. The copper-bearing mineral in all the ore was chalcopyrite. Much of the copper ore mined also carries either gold or silver, or both.

A largely increased quantity of copper ore was mined on Prince William Sound in 1916, and the production of copper, gold, and silver from the copper ores was for each metal much in excess of that of the preceding year. The future position of the Prince William Sound region as an important copper producer appears to depend on the successful treatment of the lower-grade copper ores by concentration or by a marked lowering of the mining or metallurgic costs through some radical change in methods. The completion and successful operation of the flotation plant at the Beatson Bonanza mine of the Kennecott Copper Corporation, on Latouche Island, marks an important step in the progress of this region as a copper producer.

WORK DONE DURING THE YEAR.

LATOUCHE AND KNIGHT ISLANDS.

The mining developments on Latouche and Knight islands are discussed in detail elsewhere in this volume.

UNAKWIK INLET, WELLS BAY, LONG BAY, AND GLACIER ISLAND.

Seven men are said to have been at work on the Glendenning property, on Cedar Bay, during the summer of 1916, and 400 feet of tunnel was driven. A crosscut tunnel is also reported to have been started on the property of the Wells Bay Gold & Copper Mining Co. near by. Work was in progress during the summer on the Wagner property, on Siwash Bay, a western arm of Unakwik Inlet, and on the Anderson property, on Unakwik Inlet. Assessment work is reported on a group of claims on Glacier Bay.

VALDEZ DISTRICT.

A considerable amount of underground development work was done at the Midas mine of the Granby Consolidated Mining, Smelting & Power Co. (Ltd.), on Solomon Gulch, during 1916. The main tunnel has been extended to a length of 735 feet. A 200-horsepower Diesel engine was installed at the mine and furnished power to operate a 160-horsepower compressor and also a small generator. Arrangements were being made for hoisting equipment, and it was expected that sinking would commence early in 1917. Regular shipments of ore to the company's smelter at Anyox, British Columbia, were commenced in August, 1916, and continued during the remainder of the year.

The Peabody Alaska Copper Corporation, controlling the old Addison Powell property, on Sulphide Gulch about 4 miles from its junction with Lowe River, is reported to have done annual assessment work, consisting of open cuts, stripping, and a few feet of tunneling.

ELLAMAR DISTRICT.

The plant of the Ellamar Mining Co., at Ellamar, was operated for 355 days, working two shifts a day, and a large quantity of ore was mined and shipped. The underground work was largely between the 100 and 200 foot levels, and some of the siliceous ore between the surface and the 100-foot level west of the main ore shoot has been removed. A large waste open cut has been made on the slate hill southeast of the mine. This is tapped from the 100-foot level, and the slate is used for filling. The water level in the mine has been lowered to the 500-foot level. Some diamond drilling was done on the claims owned by the company. Surface improvements made during the year include the construction of a warehouse on the dock, a new change house for the men, an addition to the bunkhouse providing for 12 men, and an addition to the cookhouse. A maximum force of 100 men was employed on the property during the year. The force during the last seven months of the year averaged about 90 men.

Although the Threeman Mining Co., on Landlocked Bay, made no shipments during the year, some underground development work was done on the Keystone claim. A raise was put through between the new third level and the second level, and some stoping was done on the third, fourth, and fifth levels. One man was at work on the property during the spring, but later in the season the force was increased to 10 men.

The Hemple Copper Mining Co., on Landlocked Bay, reports the driving of 150 feet of tunnel in 1916.

The property of the Standard Copper Mines Co., on Landlocked Bay, was leased for four years by the Alaska Standard Copper Mining Co. Work, consisting of repairs to buildings, dock, and equipment, is said to have commenced November 22, 1916.

A small lot of ore was shipped to the Tacoma smelter from the Buckeye group, near the head of Landlocked Bay, in the spring of 1916. Two men were at work on the property during the spring and one man during the summer.

Only assessment work is reported on the property of the Landlocked Bay Copper Mining Co.

PORT FIDALGO.

Development work was in progress in 1916 at all three of the copper mines on Port Fidalgo. The Fidalgo Mining Co. shipped a few hundred tons of ore during the year, drove about 250 feet of tunnels, and completed the installation of a small water-power plant. This plant was not finished till late in the season and was in operation only about a month. Water under a head of 400 feet drives a 36-inch Pelton wheel belted to a single-stage compressor with a capacity of 385 cubic feet a minute, which operates two jack hammers and one stoper. A good cropping of ore is reported to have been found during the year about 300 feet east of the old workings.

The Alaska Mines Corporation operated the old Schlosser property continuously throughout the year, with an average crew of 17 men and a maximum of 27 men. A new wharf and several new buildings were erected on the property, and considerable underground work was done. A new tunnel driven about 140 feet below the upper terminal of the aerial tram encountered ore. Ore was also mined from the upper levels. The total amount of underground work done during 1916 is said to have consisted of 350 feet of drifting and about 300 feet of raises. The first shipment of ore was made in February, 1916, and several other shipments were made later in the year. No shipments were made in 1915.

The Dickey Copper Co., owners of the Mason and Gleason claims, on Irish Cove, employed from 3 to 15 men at different times during 1916 and did between 500 and 600 feet of underground work. The wharf and ore bunkers on Irish Cove were completed early in the year. A shipment of several hundred tons of ore was made in the spring. Operations at the mine were discontinued for the year in October.

GOLD MINING.

GENERAL CONDITIONS.

The gold produced in the Prince William Sound region, other than that obtained from the gold-bearing copper ores, comes from both gold-quartz lodes and gold placers. The placer deposits, because of the recent intense glaciation of the region, are few, small, and irregularly distributed. They are worked only intermittently, on a very small scale, and contribute little to the gold production. The producing gold-quartz lodes are in the Port Wells and Port Valdez districts. The Granite mine, on Port Wells, and the Ramsay-Rutherford mine, in the Port Valdez district, are the largest producers.

WORK DONE DURING THE YEAR.

PORT WELLS DISTRICT.

The geology and economic features of the gold-quartz deposits of the Port Wells district, together with the developments up to and including 1915, have been described in recent reports.[1] The Granite mine continues to be the most productive property in the district. Small test shipments were made during the year from the Reagan group, on Culross Island, and from the Banner group, on Bettles Bay. Underground development and assessment work was done on many properties in the district, a few new lode discoveries are reported, and new milling plants were in process of erection on three propertes. Ocean-going steamers continued their visits to Port Wells, and a regular mail and passenger service was maintained between Valdez and Port Wells points. A new post office has been established at the Granite mine, and the one at Golden has been discontinued.

At the Granite mine underground development was in progress throughout the year and over 2,000 feet of workings, consisting of drifts on the several levels and a few stopes, are reported to have been opened. A new intersecting vein was discovered on the hoist level and tapped on the 50-foot level by a short crosscut. The mill was operated from January 1 to June 1, both the 10 stamps and the Lane mill being used. Milling operations ceased temporarily on June 1 and were not resumed until October 1, when only the 10 stamps were put into commission. A maximum of 65 men were employed on the property during the spring; two shifts were worked daily in the mine and three shifts in the mill. During the cessation of milling operations in the summer the working force is reported to have been cut to about 45 men. Early in October 50 men were at work on the property.

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[1] Johnson, B. L., The Port Wells gold lode district: U. S. Geol. Survey Bull. 592, pp. 195–236, 1914; Mining on Prince William Sound: U. S. Geol. Survey Bull. 622, pp. 131–139, 1915; Mining on Prince William Sound: U. S. Geol. Survey Bull. 642, pp. 137–145, 1916.

The Thomas-Culross Mining Co., on Culross Island, started the erection of a milling plant on the south side of Thomas Bay, near the head of the bay. The mill building, in process of erection in October, 1916, is about 1,350 feet from the mouth of the mine tunnel, with which it is to be connected with a ground tram, also partly completed at that time. The mill equipment, including a 10-foot Lane mill, Pelton waterwheel, and Samson jaw crusher, was on the property. Five men were employed in the construction of the plant.

Very little underground work was done on the vein on this property during the year, one man being at work for 34 days. A crosscut tunnel about 150 feet long taps the vein at the inner end of the tunnel and a drift follows the lead from this point for about 250 feet. Two shafts, 10 feet and 28 feet deep, have been sunk on the outcrop of the ore body. A new shaft house was erected during the year to take the place of the one demolished by the storms of the preceding winter.

A test shipment of gold-bearing quartz was made to Seattle from the Reagan group, on Culross Island, in February, but no work other than the annual assessment work was done on the property during the year.

A mineralized porphyry dike is reported to cut at a slight angle the bedding of the slate and graywacke series on the Golden Giant group, on the north side of Passage Canal. This property lies east of the foot of Billings Glacier, about 1 mile north of tidewater. The dike is said to have a width of 2 to 5½ feet and to be traceable for several thousand feet. The dike contains numerous quartz stringers, of various thicknesses up to 8 inches, which carry free gold, sphalerite, and galena.

Only assessment work was done on the Lone Star group, the Homestake, and the property of Dunklee & Reilly, on Pigot Bay. On the Lone Star the underground development work is said to consist of a 100-foot crosscut and a 50-foot drift on the lead.

On Bettles Bay a 250-foot tunnel was driven on a mineralized dike on the Banner group, near the entrance of the bay, at an altitude of about 148 feet. It exposes a shattered acidic dike, which ranges in width from 1 to 8 feet and averages 4 feet. The dike is reported to be traceable across the ridge from Bettles Bay to Hummer Bay, where it is said to crop out about 2,000 feet above the head of the bay. A small dike about 1 foot in width branches from the main dike in the tunnel and extends southward a few feet east of the main dike. The shattered dike is cut by numerous quartz stringers that contain gold, arsenopyrite, galena, and sphalerite. Two men were employed on the property during the winter of 1915–16, and two additional men were put on in the spring. No work was in progress during July and August, but in October work had been resumed with a force of five men. A test shipment of ore was made during the year.

Assessment work only was done on the Yakima claim, on Bettles Bay. A total of 65 feet of tunnel has been driven on the property.

On the Mineral King property, better known as the Hermann-Eaton, about 75 feet was driven on a proposed 500-foot adit which will tap the vein at a depth of 230 feet. A 10-stamp mill, five Monarch concentrating tables, waterwheels, and an air compressor were brought from the Hope district, on Turnagain Arm, and placed on the property but were not erected. About 900 feet of hydraulic pipe was installed. Work was suspended on the property about December 10, with the exception of two men hand drilling.

A galena-bearing vein was located during the summer in the hills about 1½ miles north of the Mineral King.

Four men are reported to have driven a 200-foot tunnel on a property between Hobo and Bettles bays.

The Sweepstake Mining Co. is said to have erected a 2-stamp mill on its property on Harriman Fiord. Some work is reported on the property of the Homestake Mining Co.

On Barry Arm a quartz vein is reported to have been discovered about 5 miles up from the mouth of the arm, a mile from the shore.

A 120-foot tunnel was driven during the year on the Osceola vein, on College Fiord.

Two to four men were at work during 1916 on the Consolidated claim, on Avery River, and 120 feet of tunnel is said to have been driven on the lead. On the Nugget, at Golden, 45 feet of tunnel was driven. On the Arrow Head group (H. C. Johnson and George Wagner, locators and owners), at Golden, a crosscut tunnel struck an ore vein 100 feet from the mouth of the tunnel. This vein was followed for 45 feet. In addition to this work drifts were run in both directions, a total distance of 35 feet, on a vein that crosscuts this long tunnel. Only assessment work is known to have been done on the other properties in the vicinity of Golden.

PORT VALDEZ DISTRICT.

The economic geology of the gold deposits of the Port Valdez district, with the mining developments up to and including 1915, have been described in recent reports,[1] and a detailed report on this district is now in preparation.

The producing properties in 1916 in the Port Valdez district included the Ramsay-Rutherford, Cliff, and Gold King, and those of the Valdez Gold Co. and the Mineral Creek Development Co. Small test shipments were also made from the Alice and Rambler properties. Development work was in progress on a few other properties, and the annual assessment was done on many others.

Underground development work was in progress on the claims of the Ramsay-Rutherford Gold Mining Co. throughout the year. Work was done on the 100, 150, 225, and 300 foot levels, and stoping was in progress between all these levels. Two shifts were worked daily in the mine. Milling operations continued from the previous year till the later part of January, when the water supply froze. The mill started again late in May and was reported to have been in operation the rest of the year. Three shifts were worked daily in the mill. An average of 20 men were employed on the property throughout the year.

On the property of the Valdez Mining Co., on the south side of the Valdez Glacier, 100 feet of tunnel was driven by three men.

Two men, at work during part of the summer on the Pinochle claim, drifted both ways on the vein in the lower tunnel, a total distance of about 40 feet.

The Mineral Creek Development Co. is the present owner of the Hercules and Millionaire claims, on Mineral Creek. Six men were at work on these claims from March to about the end of September. A 200-foot crosscut was driven on the Hercules claim and drifts were run on the vein for 40 to 50 feet. A small amount of work was also done on the Millionaire claim. A mill, formerly on the Big Four property, near by, was erected on property of the Mineral Creek Development Co. and was operated for about a month and a half. Surface improvements on these claims during the year were limited to the erection of the mill building. Assessment work only is said to have been done on the Little Giant, Rose, Big Four, and other properties on Mineral Creek.

The Cube Mining Co., owner of a bond on the Three-in-One claims, report the driving of 600 feet of tunnel on the vein and the installation of an amalgamation and concentration plant, in which the crushing unit is a Hardinge conical mill. During the early part of the year only a few men were at work on the property, but the force was gradually increased, and in October 15 men were employed. Drifting is reported on both levels in the mine.

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[1] Brooks, A. H., Gold deposits near Valdez: U. S. Geol. Survey Bull. 520, pp. 108–130, 1912. Johnson, B. L., Mining on Prince William Sound; U. S. Geol. Survey Bull. 592, pp. 237–243, 1914; Mining on Prince William Sound: U. S. Geol. Survey Bull. 622, pp. 131–139, 1915; The gold and copper deposits of the Port Valdez district: U. S. Geol. Survey Bull. 622, pp. 140–188, 1915; Mining on Prince William Sound: U. S. Geol. Survey Bull. 642, pp. 137–145, 1916.

Work was started on the Black Diamond group about the middle of May. An upper tunnel at an elevation of about 700 feet was started on the lead and driven a distance of 140 feet during the year. Considerable open-cut work and stripping of the vein was also done. An upper camp of four buildings was completed during the year. From one to three men were employed in the development work.

Some underground development work was done on the McCallum lode claims near the head of Gold Creek.

An average of 14 to 18 men were employed at the Cliff mine during the year. The dock was put in good condition. Underground development work was continuously in progress, but milling operations were intermittent. Three raises were put through from the 100-foot level to a prospect tunnel about 200 feet above the beach, a raise was started from that tunnel toward the next level, and a little stoping was done above the prospect tunnel. A small winze is also reported to have been sunk 40 feet below the level of the prospect tunnel, and drifts were extended each way on the vein from the bottom of the winze. A little ore was also stoped out between the 100-foot and 200-foot levels.

On the property of the Sea Coast Mining Co., on Shoup Bay, a mill building was erected at the mouth of Uno Creek, and a 10-stamp mill, jaw crusher, and two tables were installed. Three small cottages were erected near by. The building to house the hydroelectric power plant on Uno Creek was also completed, but at the time of visit all the machinery for this plant had not yet arrived on the ground. The aerial tram connecting the mine and mill was nearly completed. At the mine about 400 feet of drifting was said to have been done on the vein. An average of 20 men were at work on the property during the year.

Assessment work is reported on the Alice claim, and a small shipment of ore was made from the surface croppings. The tunnel on the Blue Bird claim, on the south side of the mouth of Shoup Bay, was extended 20 feet. On the Guthrie-Belloli claims, in Uno Basin, two men drove a new lower crosscut tunnel 90 feet in length, cutting the vein at the inner end of the tunnel. Drifts were then run about 25 feet each way along the vein. Both tunnels on the Gold Standard were extended a few feet. One man was at work on the Nymond claims during part of the summer. On the Bald Mountain group, on Shoup Glacier, between 30 and 35 feet of drifting was done in the main tunnel.

The claims of the Valdez Gold Co. (formerly known as the Cameron Johnson Gold Mining Co.) were worked during the summer with a force of 12 to 15 men. Several hundred feet of work is reported to have been done on the upper showings. The mill was run only a very short time, and only a few tons of ore was milled.

On the Tuscarora claim assessment and development work is reported to have been in progress from June 15 to the end of the year, and 45 feet of underground work was completed.

On the Rambler vein 150 feet of tunnel was driven and a shipment of ore was made for a mill test.

Assessment work is reported on the property of the Thompson-Ford Mining Co. and on the Bunkerhill and Minnie claims.

The Gold King claims, on Columbia Glacier, were operated during the year. Two men were engaged in development work during the winter, but from June 1 to September 1 this force was increased to six or eight men. No changes in the plant were made, and no new construction work was done. The mill was operated during most of the summer. The underground development work done during the year is reported to have included 230 feet of drifts and a 68-foot raise, with stopes along all of the raise.

COPPER DEPOSITS OF THE LATOUCHE AND KNIGHT ISLAND DISTRICTS, PRINCE WILLIAM SOUND.

By Bertrand L. Johnson.

INTRODUCTION.

In the present preliminary report the distribution, geologic relations, and characteristics of the copper deposits of the Latouche and Knight Island districts will be briefly described. A more complete and detailed report on these districts is in preparation.

The earliest recorded reference to either of these districts is that of Cook,[1] who in May, 1778, after a brief exploration of Prince William Sound, left those waters through Montague Strait. Portlock[2] in the spring of 1787 explored the east side of Latouche Island and part of Knight Island Passage. In June, 1794, Joseph Whidbey, of Vancouver's expedition,[3] crossed from Montague Island direct to Cape Puget, on the mainland of Kenai Peninsula, passing on the seaward side of Latouche and adjoining islands, and after traversing the shores of Port Bainbridge went through Bainbridge Passage on his way northward.

Schrader[4] visited Latouche Island while studying the geology of Prince William Sound in 1898, and again, in company with A. C. Spencer, in 1900. In 1905 Grant[5] studied these districts in greater detail. Grant and Higgins[6] made additional observations in 1908 and 1909.

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[1] Cook, James, A voyage to the Pacific Ocean [etc.] in the years 1776–1778, 3 vols., maps, London, 1784–1785. (See vol. 2, p. 364, 1785.)

[2] Portlock, Nathaniel, A voyage round the world [etc.] performed in 1785, 1786, 1787, and 1788, pp. 210–211, London, 1789.

[3] Vancouver, George, Voyage of discovery to the North Pacific Ocean [etc.] in the years 1790–1795, vol. 3, pp. 176–178, maps, London, 1798; new edition with corrections, vol. 5, pp. 300–304, 1801.

[4] Schrader, F. C., A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 354, 419–420, 1900.

Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska, pp. 15, 27, 37, 89: U. S. Geol. Survey Special Pub., 1901.

[5] Grant, U. S., Copper and other mineral resources of Prince William Sound; U. S. Geol. Survey Bull. 284, p. 82, 1906.

[6] Grant, U. S., and Higgins, D. F., Copper mining and prospecting on Prince William Sound: U. S. Geol. Survey Bull. 379, pp. 87–93, 1909. Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U .S. Geol. Survey Bull. 443, 1910. Grant, U. S., Copper deposits of Prince William Sound, Alaska: Min. and Sci. Press, vol. 100, pp. 63–64, 1910; Mining and prospecting on Prince William Sound in 1909: U. S. Geol. Survey Bull. 442, pp. 164–165, 1910.

A detailed description of the Beatson-Bonanza mine, on Latouche Island, has been given by Lincoln.[1] Notes on the mining developments of the district have been given by Moffit[2] and Johnson.[3]

The field work on which this report is based began June 19, 1916, and ended October 5, 1916. The successful completion of the work of the season was greatly facilitated by the use of the launch *Prospector*, of Cordova, in charge of Capt. George E. Scott. The conclusions presented in the text, being the results of a preliminary study of the data collected during the field season, are tentative and are subject to revision, if needed, in the more complete report.

The writer's thanks for information furnished and assistance rendered are here extended to the officials of the Kennecott Copper Corporation, at Latouche, to Mr. Hancock, at Horseshoe Bay, and to Messrs. George E. Scott, W. B. Harris, J. A. Wilson, Teening Carlson, Harry Moore, and many others.

GEOGRAPHY.

Situation.—The Latouche and Knight Island copper districts lie at the west entrance to Prince William Sound, on a northwestward-trending group of mountainous islands, of which Latouche, Knight, Elrington, Hoodoo, and Bainbridge islands are the principal members. (See Pl. XII.)

Relief.—The relief of the districts is moderately strong. The mountain summits range from 1,000 feet to a little over 3,000 feet above sea level, but only on Knight, Bainbridge, and Latouche islands do their altitudes exceed 2,000 feet. Knight Island is the most rugged of the group, and its mountains are much the highest in the districts, one peak, Mount Marion, in the southern part of the island, rising to an altitude of 3,280 feet. Along the east side of Bainbridge Island the maximum height reached is 2,351 feet, and the higher summits of the cirque-carved backbone of Latouche Island stand at 2,018 to 2,255 feet.

Glaciation.—The entire region has been intensely glaciated, but the remnants of the ice sheet which once covered these islands are few, small, and of the alpine type, none reaching tidewater. They are observed only on Knight Island. Many large glaciers, however, are present on the mainland of Kenai Peninsula, just west of this group of islands. Some of these are tidal glaciers and discharge icebergs, which, in summer, may frequently be seen floating among these islands.

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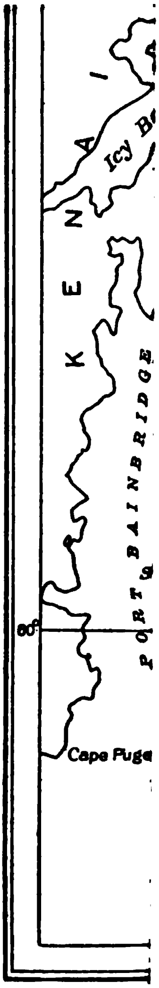
[1] Lincoln, F. C., The Big Bonanza copper mine, Latouche Island, Alaska: Econ. Geology, vol. 4, pp. 201–213, 1909.

[2] Moffit, F. H., Notes on copper prospects of Prince William Sound: U. S. Geol. Survey Bull. 345, pp. 176, 178, 1908.

[3] Johnson, B. L., Mining on Prince William Sound: U. S. Geol. Survey Bull. 592, p. 243, 1914; Bull. 622, pp. 132–133, 1915; Bull. 642, p. 139, 1916.


KENAI
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PORT BAINBRIDGE
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Drainage.—The surface waters of these islands flow directly to the numerous passages between the islands or to the many small bays indenting their shores. The streams are short and drain small areas. Most of the streams are less than a mile in length, and the longest stream has a length of but 2⅓ miles.

On some of the streams small water powers could be developed, and on Latouche Island small power plants are in operation at two properties.

Climate.—The Latouche and Knight Island districts lie within the Pacific coast climatic province, the climate of which is essentially temperate and humid, being characterized by heavy precipitation and a comparatively high mean annual temperature.

The average annual precipitation on Prince William Sound, as shown by records kept at Valdez and Cordova, ranges from about 74 inches at Valdez to about 132 inches at Cordova. In 1912 the precipitation at Cordova was 191 inches, but the rainfall in that year was exceptionally heavy. Records kept at Latouche from September 1, 1915, to September 1, 1916, by Mr. B. H. Dow, of the Kennecott Copper Corporation, showed rainfall for those twelve months of 142.26 inches. The average mean annual temperature at that place for the same period, computed from readings made at 8 a. m. daily, was 38° F. The average temperature for the three summer months was about 51° F., and the average for the three winter months about 27° F.

Timber.—The Latouche and Knight Island districts are included within the Chugach National Forest and are abundantly timbered. Timber line ranges from 1,000 to 1,500 feet above sea level. Most of the smaller islands are completely covered with timber, and many of the larger islands have only a few peaks or ridges rising slightly above timber line. The largest untimbered areas are on Knight Island. The forest trees include spruce, western hemlock, mountain hemlock, and alder. Coniferous trees, 4 to 5 feet in diameter, are occasionally found, but the average diameter of the larger trees is probably from 1 to 2½ feet. Timber suitable for most purposes can be cut near most of the mines and prospects, but the better grades of lumber must be brought from Seattle. Dressed lumber can also be purchased at Valdez.

Population and settlements.—The population of these districts is dependent upon the mining industry, and the existing settlements are at or near mines or prospects. Latouche, the largest settlement, with a population of about 400, is on the west coast of Latouche Island near its north end. This settlement has been built up close to the Beatson-Bonanza mine. Most of the supplies necessary for prospecting are obtainable here at the mine store of the Kennecott Copper

Corporation. Gasoline, however, was obtainable in 1916 only in 10-gallon lots, at 45 cents a gallon.

Several houses have been built on Horseshoe Bay on the west side of Latouche Island near the prospects of the Reynolds Alaska Development Co., and in 1916, while development work was in progress, about 15 persons were living at that place.

Latouche serves as a distributing point for much of these districts, but a considerable number of the Knight Island property owners use either Valdez or Ellamar as a supply point. Public wharves are available at Valdez and Cordova for the transshipment of machinery and supplies from the ocean-going steamers arriving from the States to the smaller boats that are available for trips to the prospects. There are no public wharves in these districts. The wharf at Latouche used by the regular steamers is the property of the Kennecott Copper Corporation. Hotel accommodations are available only at Valdez and Cordova, although quarters for visiting engineers have been furnished at the mines.

Transportation.—Transportation facilities to and from points in the United States are fairly good. Latouche, the only port of call within these districts, is on the regular routes of travel for ocean-going steamers of two lines running to southwestern Alaska points. There are about nine passenger boats each way a month in the summer and about five a month in the winter. The passenger boats carry freight, and there are also several boats engaged exclusively in freight transportation. Passenger rates in 1916 were the same on both lines for all Prince William Sound points, and were as follows: First class, upper deck, $50; first class, lower deck, $47.50; steerage, $30. Freight charges from Seattle to Prince William Sound point in 1916 ranged from $3 to $45 a ton according to classification. First-class passenger fare on the large boats between Valdez and Latouche is $5 each way; steerage, $3 each way.

Local travel is entirely by small boats. There is no regular service, but gasoline launches are usually available at Latouche and are apparently more abundant and more readily obtainable at Valdez.

As water routes are used for practically all transportation between mining camps and their supply points and the conditions for water travel are so favorable and those for land travel so difficult, little has been done to construct or improve roads or trails between camps, and those already constructed are restricted to trails from the shore camps to the mines and prospects. A United States post office has been established at Latouche for several years. In the summer of 1916 a wireless plant, reported to be of sufficient power to communicate with stations at Kodiak and Cape Whitshed and approaching steamers was erected at Latouche.

GEOLOGY.

PRE-QUATERNARY ROCKS.

The pre-Quaternary rocks of these districts include both sedimentary and igneous types. The sedimentary rocks are all regionally metamorphosed and may be segregated into two distinct groups—(1) the graywackes, slates, argillites, and conglomerates of Latouche, Knight, Flemming, Hoodoo, and Elrington islands and of the eastern and southern parts of Bainbridge Island and (2) the massive graywackes of Kenai Peninsula and the western part of Bainbridge Island. All the igneous rocks of both districts are in this preliminary report grouped under the general term "greenstones."

GRAYWACKE, SLATE, ARGILLITE, AND CONGLOMERATE OF LATOUCHE, KNIGHT, HOODOO, FLEMMING, AND ELRINGTON ISLANDS.

The sedimentary rocks of Latouche, Danger, Knight, Hoodoo, Flemming, and Elrington islands and of the eastern and southern parts of Bainbridge Island consist chiefly of graywacke, slate, argillite, conglomerate, and a very small amount of limestone. It is probable that this group will eventually be separated into a considerable number of formations. At present several lithologic units are recognized and will be described briefly.

The oldest unit, which crops out in a wide belt on Discovery Point, on the south side of Snug Harbor, Knight Island, is composed of fine-grained dark-gray, slightly calcareous slate, with thin layers of coarser-grained lighter-gray slate rarely exceeding 2½ inches in thickness and spaced from 1 inch to 9 inches apart. These thin layers are in places intricately folded. The slates also contain small brown-weathering, slightly calcareous nodules, some of which attain a thickness of about 15 inches, and a few thin beds of limestone, including one 6 inches thick. The slates are thinly cleavable in places.

Overlying these slates is a thick succession of thin-bedded graywacke, which covers most of the drainage area of Hogan Bay and the eastern half of Latouche Island. The thickness of the individual graywacke beds ranges from 1 foot to 30 feet, but the average bed measures 10 feet or less. On Knight Island this formation contains, near the lower contact, a few layers, 5 to 50 feet in thickness, of thin-bedded argillite resembling the slate on Discovery Point, but slightly more siliceous. The graywacke is rather light colored. The argillitic beds are dark gray and are in places much iron stained. The bedding in the graywacke is sharply defined and clean cut, individual beds separating readily from each other.

On Latouche Island a thick mass of slate and argillite lies above the bedded graywacke. This is overlain by another graywacke series, above which is a group of alternating slate, graywacke, and argillite, with some chert and limestone. A band of black slate of considerable width passes through Latouche. Conglomerate crops out in a narrow belt at Latouche and on Little, Horseshoe, and Pleasant bays. The conglomerate contains numerous small, well-rounded pebbles of both sedimentary and igneous rocks, of which quartz, quartzite, chert, argillite, slate, light-colored fine-grained granitic rocks, and both light and dark colored porphyries are the most abundant, also many fragments of slate and argillite. Above the conglomerate beds is more graywacke, overlain by a mass of slate carrying but little graywacke, which forms the west coast of Latouche Island from Horseshoe Bay to Pleasant Bay.

The sedimentary rocks on Hoodoo, Flemming, and Elrington islands and the east side of Bainbridge Island are largely slate, with minor amounts of graywacke and conglomerate. The conglomerate is most prominent on the northeast shore of Hoodoo Island near Bishop Rock but occurs also on Elrington Island near the south end of Elrington Passage and on Knight Island between Mummy and Little bays. It is similar to those found on Latouche Island.

Fossils have been found within this group at several localities, but with one exception they have not proved of diagnostic value. A comatulid crinoid was found in the slates on the west side of Hoodoo Island. J. B. Reeside has reported on this specimen as follows:

> 16 AJ 73 (10014), Hoodoo Island: Centrodorsal and two arms of a comatulid crinoid referred by A. H. Clark to an undescribed genus of the subfamily Bathymetrinae of the family Antedonidae. The comatulids as a group are unknown before the Jurassic and are always rare as fossils. The specimen represents a type most abundant in recent seas and is much like a living Alaskan form. Knowledge of the fossil forms is so scant that an exact statement of age is impossible, though the close relation to a living crinoid suggests Cretaceous or later.

The age of this group of apparently conformable formations can not therefore be given more closely than post-Triassic, with the added suggestion that this group, the oldest of the region, may be Cretaceous or later.

GRAYWACKE OF WESTERN BAINBRIDGE ISLAND AND KENAI PENINSULA.

The bedrock of the western part of Bainbridge Island and the eastern shore of Kenai Peninsula is a group of sedimentary rocks, composed of interbedded graywacke, argillite, slate, and conglomerate. The eastern limit of this group extends from the bay in the north end of Bainbridge Island southwestward to Hogg Bay. The western limit is unknown. This group is made up largely of graywacke, but the proportion of other types of sedimentary rocks varies widely. At the north end of Bainbridge Island there is a broad belt of slate and graywacke, to the west of which lies a high ridge of massive graywacke. The west shore of Bainbridge Island and the west side of Bainbridge Passage consist of very massive graywacke with very little slate. This group must comprise several thousand feet of strata. The formations as a whole are of a dark-gray color; the slate is bluish black, and the graywacke dark gray. The graywacke of Bainbridge Passage differs from the bedded graywacke of Latouche Island in the absence of definite, straight, and abundant bedding planes. Here and there narrow belts of thin-bedded graywacke and argillite show in the more massive graywacke. On Hogg Bay, on Bainbridge Island, some conglomerate occurs interbedded with slate, argillite, and graywacke. The matrix of the conglomerate ranges from siliceous to argillaceous. The pebbles are small and well rounded. A noteworthy feature of this conglomerate is the presence in it of greenstone pebbles. The conglomerates of Latouche, Hoodoo, and Knight Islands are not known to contain pebbles of similar lithologic character.

So far as is known at present this is the youngest rock group in the Latouche and Knight Island districts. No fossils have yet been found in any part of the group, and therefore exact evidence as to its age is not available. Nor are its contacts with the other rock groups of these two districts sufficiently distinct to permit definite statements as to its age relations. The situation of this group to the west of and apparently overlying the other groups; the absence of basic intrusions in it; the more massive character of the graywacke of this group as opposed to the bedded nature of the graywacke of Latouche and Knight islands; and the presence of greenstone pebbles in the conglomerate on Hogg Bay, all appear to indicate a later age for this group of rocks, with a probable marked erosional unconformity between it and the next older greenstone group. The evidence on this point, however, is not conclusive, and it is possible that this group is to be correlated with the bedded graywacke of Latouche and Knight islands.

GREENSTONES.

The rocks locally called greenstones are greenish altered igneous rocks, comprising a thick series of lava flows, volcanic tuff, and agglomerate, with associated dikes and larger intrusive igneous masses. All these rocks are basic. They intruded or flowed out over the surface of the graywacke, slate, and conglomerate which form the sedimentary portion of the eastern islands of this group, and they appear to be overlain by the massive graywacke of western Bainbridge Island and Kenai Peninsula. The different types are intimately associated, are probably genetically related, and are of about the same age. No very definite evidence is available regarding the age of these igneous rocks, and at present it can only be said that the volcanic activity took place either in the Jurassic or in some later period.

The greenstones are the most widespread group of rocks in these districts. They cover all of Knight Island except the peninsula between Snug Harbor and Mummy Bay, which is composed of sedimentary rocks that are older than the greenstone but are intruded by many sills, dikes, and masses of it. Elrington Island, except for a small central portion, is almost wholly greenstone. Hoodoo and Flemming islands are largely greenstone, and intercalated in the slates of the eastern and southern parts of Bainbridge Island are many basic sills. A few small sills also intrude the rocks of Latouche and Danger islands. The largest single area of igneous rock is that of Knight Island. This area extends from Point Eleanor south to the entrance of Mummy Bay, a distance of a little over 25 miles, and its maximum width is about 9 miles.

The greenstones vary widely in texture, ranging from aphanitic to coarse-grained rocks. Both porphyritic and nonporphyritic types occur. Diabasic and amygdaloidal textures are also seen. The color of the rocks varies considerably, ranging from light greenish gray to dark greenish black. Some of the rocks have slight reddish tints, and fragments of reddish lava occur in some of the agglomerate. Ellipsoidal flow structure is visible in many places along the shores of Knight Island, but the rock in the central part of the island is more massive, shows little evidence of ellipsoidal structure, and presents wide color and textural ranges. Gneissic texture is shown in places. Ellipsoidal structure is also found on Flemming, Elrington, Hoodoo, and some of the smaller islands. Tuffaceous and agglomeratic beds occur on Elrington and Knight islands. Dark-colored fine-grained basic dikes cut both the ellipsoidal greenstones and the central massive core of Knight Island in several places. In some parts of the districts chloritic schist has been developed by the shearing of the greenstones by later movements.

MINERAL RESOURCES.

GENERAL FEATURES.

The mineral resources of the Latouche and Knight Island districts consist of lode deposits containing as valuable metals copper, silver, and gold. Copper is the predominant valuable metal in the lodes of both districts, but silver or gold or both are obtained from the copper-bearing deposits.

The first mineral locations on both Latouche and Knight Islands appear to have been made in 1897. The Beatson-Bonanza mine was the first property staked. Other locations on both islands followed, but little work was done on most of the property. Development work was started on the Beatson property, and a small trial shipment of ore was made in 1889. Other shipments followed, and in 1903 over 100 tons was shipped. Regular shipments from this mine began in 1904 and have continued ever since.

Prospecting was especially active in these districts from 1903 to 1907, and culminated in the latter year in a decided copper boom. Practically all of Latouche and Knight islands was staked at that time, and many of the locations were made on showings of little worth under any conditions. Extensive developments were started on several properties. The boom did not last long, however, and its natural collapse was assisted by a sharp drop in the price of copper and the period of financial stringency of 1907 and 1908. In but few places has the development work in progress at that time been continued or renewed. No new regular producers have appeared. Test shipments, some of which amounted to several hundred tons, have been made from a number of properties on Latouche and Knight islands, and small trial shipments have been made from some of the other properties.

The world-wide demand for copper that began in 1914 caused renewed activity in this portion of Prince William Sound, and, although there has been no increase in the number of producers, the Kennecott Copper Corporation has markedly increased the productive ability of the Beatson-Bonanza mine. In 1916 development work was in progress at this mine and on the properties of the Reynolds Alaska Development Co., on Horseshoe Bay, and the Seattle Alaska Copper Co., on Montgomery Bay, on Latouche Island; and the annual assessment work was done on numerous other claims.

The area considered in this report lies entirely within the Valdez recording district, the recording office of which is at Valdez.

GEOGRAPHIC DISTRIBUTION OF THE COPPER DEPOSITS.

The Latouche and Knight Island copper districts are the southwesternmost two of several more or less isolated copper-bearing districts that lie scattered along the shores of Prince William Sound from Cape Whitshed to Cape Puget.

The copper mineralization in the southwestern part of Prince William Sound is, so far as known, restricted to the islands of the Latouche and Knight Island districts. These two districts are more or less mineralized throughout their entire length and breadth, and consequently the mineral belt trends northeastward with the general geographic trend of the islands included in the districts. Copper deposits have been found on Knight, Latouche, Elrington, and Bainbridge islands. They are especially abundant in the greenstones on Knight Island, although it is in the sedimentary rocks of Latouche Island that ore bodies of proved commercial value have thus far been found. The known deposits on Elrington and Bainbridge Islands are few, small, and economically unimportant, but they serve to show the widespread extent of the mineralization.

The mineralization has a known vertical range of at least 1,550 feet. It is found below sea level in the Beatson Bonanza mine, on Latouche Island, and extends to an altitude of 1,500 feet at prospects on both Latouche and Knight islands. Copper deposits have been found distributed throughout this vertical range.

The only regularly producing property within these two copper districts is the Beatson-Bonanza mine of the Kennecott Copper Corporation, at Latouche. Small shipments of copper ore have been made to smelters from prospects on both Latouche and Knight islands.

GEOLOGIC RELATIONS OF THE ORE DEPOSITS.

Certain definite geologic conditions, partly structural and partly chemical, have caused the present geographic distribution of the ore deposits. The mineralizing solutions appear to have been genetically related to the basic intrusive rocks. The ore deposits occupy brecciated or sheared zones in both the sedimentary rocks and the greenstones of these districts. The steeply dipping sediments of Latouche and Knight islands are crosscut and intruded by the greenstones, and the bedding planes of these sedimentary rocks, together with the many dip and strike faults, offered favorable channels for the ore solutions. Shear zones were also developed in the greenstones of Knight Island by diastrophic movements during the succession of intrusions and extrusions which built up that island. Many of these shear zones are more or less mineralized.

Within the greenstone area of Knight Island evidences of sulphide mineralization are so abundant as to indicate a source near by for the mineralizing solutions. The presence of chalmersite within this area is perhaps significant of the same thing. The mineralization of the other greenstone areas of the Latouche and Knight Island districts is slight, and prospects are known only on Elrington and Bainbridge islands.

Many copper-bearing prospects have been found within the older sedimentary rocks both on Knight and Latouche islands. It is within these rocks that the ore bodies of the Beatson mine at Latouche, the Reynolds Alaska Development Co.'s prospect at Horseshoe Bay, and the other Latouche Island properties lie. Sporadically distributed through certain portions of these rocks are limestone and other calcareous sediments. At Horseshoe Bay undigested fragments of limestone are found in the solid sulphides, and beds of siliceous limestone were cut in some of the workings. The upper argillaceous part of this group of the older sedimentary rocks, as exposed on Elrington, Hoodoo, and Bainbridge islands, appears to have presented unfavorable conditions to the formation of sulphide ore deposits.

No copper deposits are known to have been found within the areas underlain by the massive graywacke series of western Bainbridge Island and the adjacent mainland of Kenai Peninsula, which apparently were laid down after the cessation of cupriferous mineralization.

The ore bodies are impregnation and replacement deposits of sulphide ores. Classified on the basis of the dominant valuable metal, the ores are copper ores. From a metallurgist's point of view they are base smelting sulphide ores with a high copper content.

The mineralogy of most of the ores is simple; the minerals are few and are common to most of the properties. Certain of the Knight Island prospects, however, contain chalmersite, a rare copper-iron sulphide not observed in most of the copper-bearing ores of the two districts.

The economically important copper-bearing minerals are chalcopyrite and chalmersite, which occur intimately associated at some of the Knight Island prospects. Gold or silver, or both, occur in some of the ores. The gold is probably native. The combination in which the silver occurs is not known.

The original metallic minerals of these ores are chalcopyrite, chalmersite, pyrrhotite, pyrite, sphalerite, galena, gold, and silver. Traces of arsenic and nickel are reported in some of the ores. The nonmetallic minerals include quartz, feldspar (?), chlorite, a brown-weathering cream-colored carbonate, calcite, and epidote.

Minerals resulting from the weathering of the original ore minerals are native copper, chalcocite, covellite,[1] melaconite,[2] malachite, azurite, and the yellow and red oxides of iron. These secondary minerals are of no economic importance because of their scarcity, the ore bodies having been but slightly oxidized since the comparatively recent glaciation of these districts.

MINES AND PROSPECTS.

The descriptions of the mine and prospect workings as here given must be regarded in the main as representing the conditions in the fall of 1916. All the prospects within these two districts were not visited in 1916, and consequently no description can be given here of the prospects not seen. The absence of people on many of the bays and the fact that only a few properties were under development during the summer prevented the visiting of many prospects and the obtaining of more detailed descriptions of many others. In the following descriptions the elevations have ordinarily been obtained by the use of aneroid barometers. The distances underground were measured by pacing. All bearings have been corrected for magnetic variation. The amount of space devoted to a prospect is no measure of its economic value.

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[1] Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, p. 54, 1910.

Lincoln, F. C., The Big Bonanza copper mine, Latouche Island, Alaska: Econ. Geology, vol. 4, p. 212, 1909.

[2] Grant, U. S., and Higgins, D. F., op. cit., p. 54.

LATOUCHE ISLAND.

KENNECOTT COPPER CORPORATION.[1]

The property of the Kennecott Copper Corporation is on the west side of Latouche Island, about 2½ miles from the north end of the island. (See Pl. XII.) The mill, power plant, and other camp buildings are on tidewater. The Beatson-Bonanza mine, on the Big Bonanza No. 1 claim, is in the precipitous western face of a low hill about half a mile southeast of the wharf. The Chinega workings are little over 1,000 feet north of the Beatson-Bonanza mine, on the Chinega claim.

The ore body now under development at this property is that of the Beatson-Bonanza mine. It was located in July, 1897. The first shipment of ore is said to have been made in November, 1899. In recent years shipments have been made regularly, and the mine has steadily increased its output. An oil flotation plant was put into operation in 1915, and both crude ore and flotation concentrates have since been shipped. In 1916 the capacity of the mill was being largely increased.

A large private wharf furnished landing facilities for ocean-going steamers. A tram line, covered with snowsheds, connects the wharf with ore bunkers, store, mill, and the Beatson-Bonanza workings. Large ore bunkers have been erected on the wharf and on the shore near by. Bunk houses, mess house, staff house, office, store, cabins, hospital, mill, wireless plant, power house, and crude-oil storage tanks are situated along the shore of the bay. The power plant consists of boilers fired with crude oil, steam turbines, air compressors, and dynamos. The mill is electrically operated, and the entire property above ground and part of the mine are electrically lighted. Air drills are used in the mine.

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[1] Other descriptions of this corporation's property on Latouche Island are given in the following publications:

Grant, U. S., Copper and other mineral resources of Prince William Sound: U. S. Geol. Survey Bull. 284, p. 82, 1906.

Lincoln, F. C., The Big Bonanza copper mine, Latouche Island, Alaska: Econ. Geology, vol. 4, pp. 201–213, 1909.

Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, pp. 63–66, 1910.

The underground workings of the Beatson-Bonanza mine in October, 1916, comprised a large open cut (the Bluff pit), workings on the face of the bluff, several tunnels in the face of the bluff, several large open cuts on the top of the hill east of the bluff, the main level, with nearly 6,000 feet of drifts and crosscuts, several raises to the Bluff pit, a 100-foot winze from the main level to the 100-foot level, and about 1,750 feet of workings on the 100-foot level. A main working shaft has also been started near the mill and connected with the main level.

On the adjacent Chinega claim the underground developments are reported to consist of two tunnels, some drifts, and a raise, aggregating a few hundred feet.

The ore taken from the Beatson-Bonanza mine is of two grades—a shipping ore and a milling ore. The higher-grade ore is shipped direct to the Tacoma smelter. The lower-grade ore is crushed and classified, and the sulphides are recovered by an oil-flotation process. The concentrates, after drying, are shipped to the Tacoma smelter.

The country rock on this property consists of an interbedded series of sedimentary rocks disturbed by many small strike and dip faults, and minor drag folds. The rocks range from very fine-grained black slate and argillite and light-gray structureless chert to coarse-grained light-gray graywacke and conglomerate. At the Beatson-Bonanza mine graywacke, chert, slate, and argillite form the country rock of the ore body. Between the mine and the shore is a wide slate belt, and on Powder Point occur conglomerate and graywacke. The strike of the sedimentary rocks near the Bonanza ore body is about N. 20° E. and the prevailing dip is 65°–70° W. Steep easterly dips appear locally short distances west and north of the Beatson-Bonanza workings. No igneous rocks are known to occur in the vicinity of the ore bodies.

The Beatson-Bonanza ore body consists of a roughly lenticular mineralized mass of shattered and sheared sedimentary rocks. The steeply westward-dipping interbedded sediments of the ore zone are cut by a linked system of faults inclosing large horses of country rock surrounded by softer sheared material. On the lower level the ore body has a northeasterly strike and a steep westerly dip. On the main level the strike is slightly more northerly. The hanging wall of the ore zone is sharp and definite. On the footwall side the ore gradually fades out into the massive graywacke. The ore has been formed by replacement and impregnation of the country rock and filling of fractures. The soft sheared material surrounding the horses of country rock is largely replaced by sulphides. Lenses of solid sulphides as much as 10 feet in thickness occur in places close to the hanging wall. Much of the graywacke within the ore body contains disseminated chalcopyrite.

The ore body on the Chinega claim is reported to be a shear zone containing chalcopyrite and other sulphides in streaks of solid sulphides as well as disseminated through the sheared material.

The primary metallic minerals in the Bonanza ore include chalcopyrite, pyrrhotite, pyrite, sphalerite, galena, silver, and gold. Traces of arsenic and nickel have been revealed by assays.[1] Chalcopyrite is the only copper-bearing mineral present in the primary ore. Chalcopyrite, pyrrhotite, and pyrite are the dominant sulphides; sphalerite occurs in much smaller amounts, and there is only a little galena. Only a trace of gold is shown by assays.

The primary nonmetallic minerals form but a small percentage of the ore. They include quartz, a brown-weathering cream-colored carbonate (probably the same mineral referred to by Lincoln[1] as ankerite), calcite, and chlorite. Secondary minerals, formed by the weathering of the outcrop of the ore body and by the weathering of ore pebbles in the overlying talus and glacial till, include native copper, covellite,[2] chalcocite, malachite, and limonite.

REYNOLDS ALASKA DEVELOPMENT CO.

The Reynolds Alaska Development Co. holds several claims on Horseshoe Bay, on the west coast of Latouche Island, about 2 miles southwest of the Beatson-Bonanza mine. The company has built a small town on the shore of Horseshoe Bay. A corduroy road leads from the shore camp to the mine workings on the Duke and Duchess claims, at elevations of approximately 150 and 400 feet, respectively, and distances of half and three-quarters of a mile from the shore of Horseshoe Bay.

The ore bodies on this property are said to have been located about 1898. Grant[3] states that in 1905 a 50-foot tunnel had been run on the southern ore body and a branching tunnel 300 feet in length driven on the Duchess claim. In 1907 a shaft was sunk on the Duke claim and a small amount of ore was shipped. The wharf, electric-light plant, trading store, and a number of houses were also erected during that year.[4] in 1908[5] the shaft, reported to be 100 feet deep, with a crosscut at its bottom to an ore body, was full of water. At that time the development work on the Duchess claim consisted of about 2,000 feet of tunneling. An average force of 10 men was employed in 1916. The shaft on the Duke claim was pumped out, and the drifts along the ore body were extended. On the Duchess claim development work was in progress on the lower level.

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[1] Lincoln, F. C., The Big Bonanza copper mine, Latouche Island, Alaska: Econ. Geology, vol. 4, p. 209, 1909.

[2] Idem., p. 212.

[3] Grant, U. S., Copper and other mineral resources of Prince William Sound: U. S., Geol. Survey Bull. 284, p. 85, 1906.

[4] Moffit, F. H., Notes on copper prospects of Prince William Sound: U. S. Geol. Survey Bull. 345, p. 178, 1908.

[5] Grant, U. S., and Higgins, D. F., Copper mining and prospecting on Prince William Sound: U. S. Geol. Survey Bull. 379, pp. 88–89, 1909.

On the Duke claim, in 1916, there was a 110-foot two-compartment timbered shaft, with a 200-foot crosscut 100 feet below the collar of the shaft, cutting the ore body 100 feet from the shaft, and with drifts 44 and 67 feet in length along the footwall of the ore body to the south and to the north, respectively. A crosscut was also being started west from the shaft at the 100-foot level. A short distance southeast of the shaft a 60-foot tunnel has been driven southward along a solid sulphide lens. On the north side of the creek, north of the shaft, a prospecting tunnel has been driven. Some stripping and open-cut work has also been done. The Duchess workings comprise two main tunnels at elevations of approximately 400 and 500 feet, with drifts and crosscuts aggregating 1,000 and 1,800 feet, respectively, a 10-foot tunnel at an elevation of about 630 feet, and some open cuts and strippings.

Surface improvements other than those previously mentioned include the power plant on the shore of the bay, consisting of flume and pipe line leading to a Pelton wheel belt-connected to one alternating-current generator and one direct-current generator; transmission lines to both the Duke and the Dutchess workings; a continuous-current electric motor gear-connected to hoist, a small motor-driven fan for ventilating, a motor, and an electric pump at the Duke shaft; a motor (belt-connected to air compressor), air line, and drills on the Duchess claim; and buildings near both workings. A stream running through the property furnishes water power.

The country rock in the vicinity of the ore bodies consists principally of interbedded graywackes and black slates. There is also some light-gray slate, a little chert, and a small amount of limestone. Beds of light-gray siliceous limestone are exposed in the Duke workings. The bedding of these sedimentary rocks strikes N. 16°–38° E., and the dip is mostly westward, ranging between 55° W. and 83° E. There is some faulting more or less parallel to the strike and dip of the bedding. One gouge-filled fault, cut in the lower workings on the Duke claim, strikes N. 30° E. and dips 50° W. The footwalls of both the Duke and the Duchess ore bodies consist of thick beds of black slate. Graywacke predominates in the hanging walls.

Two mineralized bodies of rock have been under development on this property. These lie along a northeastward trending line and are separated by a heavily covered unprospected area nearly 1,500 feet in length, in which a small exposure of ore is said to have been observed in the bed of a stream. The northeasterly ore-bearing body, developed by the Duchess workings on two levels about 100 feet apart, consists of a solid sulphide lens with a developed length of about 500 feet. The thickness of this lens ranges from 6 inches to 122 feet, but the average is probably between 25 and 30 feet. Some beds of graywacke and black slate are interbedded with the sulphides in the thicker portion of the lens. The strike of this sulphide lens is a little east of north, and the dip is nearly vertical. A shear zone 1 inch to 8 feet thick follows the hanging wall of the lens, and a little ore in stringers and lenses occurs scattered through the sheared material. Chalcopyrite is reported to be more abundant in this shear zone than in the solid sulphide lens. The graywacke hanging wall is also slightly mineralized.

The sulphides in the ore are chiefly pyrite and pyrrhotite. Chalcopyrite is the copper-bearing mineral, and sphalerite and galena (?) are also present. There is a small gold and silver content. Small unreplaced remnants of limestone are visible in the heavy sulphide ore. Some quartz is present in the ore, and small sulphide-bearing quartz stringers occur in the country rock adjacent to the ore body.

On the Duke claim the width of the outcrop of the mineralized zone appears to be between 200 and 250 feet. The shaft developments show but a single ore body—a westward-dipping sulphide lens with a maximum thickness of 27 feet and a developed length of about 140 feet. Where this lens is crosscut the hanging wall dips 80° E. and the footwall 65° W.; the strike is about N. 35° E. Isolated mineralized croppings occur whose relations to one another and to the sulphide lens shown in the shaft workings are not known. A 60-foot tunnel has been driven southward along a 5-foot sulphide lens a short distance southeast of the shaft. This lens strikes N. 20°–45° E. and dips 60°–75° W. In the creek north of this tunnel 10 feet of solid sulphides is exposed, and another outcrop on the north side of the creek shows 6 feet of solid sulphides.

The sulphides in the Duke ore include chalcopyrite, pyrite, and pyrrhotite. Quartz is present in small amounts as a gangue mineral.

LATOUCHE COPPER MINING CO.

The ore body under development on the property of the Latouche Copper Mining Co. is on the Blackbird claim, about half a mile north of the Beatson-Bonanza mine of the Kennecott Copper Corporation and about 2,000 feet from the shore. The ore body crops out at an elevation of about 400 feet above sea level, and the mouth of the long crosscut tunnel giving entrance to the workings is about 200 feet above sea level and 1,500 feet southeast of the shore end of the tram.

The underground developments on the property consist of a crosscut tunnel, about 750 feet in length, commencing on the White Wing claim and driven in a direction a little south of east, cutting the formation nearly at right angles and crosscutting the ore-bearing ground on the Blackbird claim. There are also about 600 feet of drifts and crosscuts, some stopes, and raises, one of which reaches the surface. A 35-foot crosscut tunnel has been driven a few feet above sea level at the shore end of the tram.

The surface developments consist of numerous open cuts, some shallow shafts, trenches, and pits on and across the ore zone. A blacksmith's cabin has been erected at the mouth of the long crosscut tunnel, and two small sheds stand near by. A tram line connects this tunnel with ore bunkers on shore. Several hundred tons of copper ore is said to have been shipped from this property.

The country rock of the ore body includes fine-grained graywacke, black and gray slates, gray chert, silicified limestone, and a little calcareous schist.

The ore deposit consists of a mineralized brecciated zone of interbedded sedimentary rocks. The width of the mineralized zone at the outcrop is about 40 feet, and the length, as exposed, is about 325 feet. The general strike of the outcrop is N. 5° E. Underground the strikes of the shears within the ore zone range from N. 5° E. to N. 35° E. and the dip from 75° to 85° W.

Sulphide-bearing quartz stringers and lenses occur within the ore zone. The minerals observed in the ore are chalcopyrite, pyrite, pyrrhotite, sphalerite. limonite, quartz, and calcite.

SEATTLE-ALASKA COPPER CO.

The property of the Seattle-Alaska Copper Co. is on Montgomery Bay, on the west side of Latouche Island, about 2 miles from its south end and 6 miles southwest of Latouche. Part of the camp buildings, consisting of two houses and two sheds, are on the shore of the bay. A wet trail meanders upward through timber dotted with open spaces from the camp buildings to the mineral deposits under exploitation. At an elevation of 700 feet, near timber line, there is a frame house and a wooden mill building. The mill building houses a Pelton wheel driving an air compressor. The air is piped to the working face of the lower tunnel. Most of the milling machinery has been removed from the property, and only a crusher and a table remain. The mill is reported to have been erected about 1911 and to have run only a short time. A telephone line extends from the mill to the lower tunnel.

The mine workings are above timber line in the north wall of a westward-facing cirque at elevations of 1,150 to 1,450 feet. The lower tunnel, at an elevation of 1,150 feet, is 400 feet in length. In August, 1916, three men were at work in this tunnel, and one air drill was being operated. The next higher tunnel, at an elevation of about 1,350 feet, has about 400 feet of workings. At an elevation of 1,450 feet is a 40-foot tunnel, just above which is an open cut on the outcrop of the ore body. A short tunnel is reported in the north side of the same ridge in which the above tunnels are driven. The company is also reported to own several claims on the south end of Latouche Island, but no development work has been done on these claims recently.

The country rock in the vicinity of the ore deposit is dominantly graywacke with a small amount of black argillite and slate. The strike of the bedding is northeast, and the dip is about 70° W., with some vertical and some steep easterly dips on the limbs of small drag folds.

The ore body is apparently a mineralized shear zone ranging in width from an inch or less to 5½ feet. The strike is N. 35°-50° E. and the dip 70°-80° W. An open cut on the outcrop of the ore body exposes a mineralized sheared slaty lens, with a maximum width of 3.3 feet, containing narrow stringers of sulphides parallel to the schistosity. In the upper tunnel the sheared zone is only slightly mineralized and has a maximum width of 3 feet. The middle tunnel contains two drifts 20 and 50 feet in length driven on mineralized shear zones ranging from 18 to 66 inches in thickness.

Chalcopyrite is the predominant sulphide in the ore, but some pyrrhotite and a little sphalerite were also observed. Gold is reported in assays. Quartz is present in small amounts as a gangue mineral.

LATOUCHE ISLAND COPPER MINING CO., LTD.

The claims of the Latouche Island Copper Mining Co. (Ltd.) are on the eastern timbered slope of Latouche Island. The first showings are said to have been discovered between 1897 and 1899. Several hundred feet of tunnels have since been driven on widely scattered showings at elevations ranging from sea level to 700 feet above sea level. A two-compartment shaft has been sunk to a depth of 67 feet on one of the claims, and two log cabins and a large frame bunk and mess house have been erected near by. Several small shipments of ore are said to have been made since 1905. Only assessment work is reported on this property in recent years.

The country rock on the east side of Latouche Island consists of graywacke in beds from a few inches to several feet thick interbedded with some black slate and argillite and a little chert. The bedding has a northeasterly strike and dips 40°-65° W. There are numerous faults parallel or nearly parallel to the bedding in strike and dip. Overturned drag folds show in places along the shore.

Many mineralized showings are reported on the different claims. Several of these were visited in 1916, but only the more promising ones are referred to here. The southernmost ore body examined was a 10-foot mineralized shear zone carrying considerable chalcopyrite exposed in a creek bank at an elevation of about 600 feet above sea level and also crosscut by a tunnel about 50 feet lower. On account of the heavy timber cover no attempt has been made to determine the length of this deposit. On the Alameda claim the graywacke along shore is mineralized for widths ranging from 4 to 40 feet, and this mineralized zone is traceable for some distance. Chalcopyrite occurs in small bunches and stringers scattered through this zone but is said to be the most abundant in a belt 4 to 10 feet in width. On another claim to the north of this one a 4-foot mineralized shear zone is exposed for a short distance. All the ore bodies are parallel or nearly parallel to the strike and dip of the bedding of the country rock. Chalcopyrite, pyrrhotite, sphalerite, and quartz are the usual ore minerals.

PROSPECTS ON KNIGHT ISLAND.

LOUIS BAY.

A 10-foot adit has been driven at sea level on a poorly delimited shattered zone in the greenstone on the south side of Disk Island. This zone strikes N. 55° E., dips 75° E., and is traceable for about 50 feet to the point where it disappears under cover. It has a maximum width of 4½ feet. The country rock consists of fine-grained dark-green greenstones and coarser light-colored greenstones. The shattered greenstone is both silicified and epidotized, and the ore contains, besides quartz and epidote, the sulphides pyrite, pyrrhotite, and chalcopyrite. Malachite and azurite occur as surficial oxidation products. Pyrite also occurs in the joint cracks of the hanging-wall greenstone.

A little development work has been done on some slightly mineralized areas near the head of Louis Bay. Two tunnels, each about 10 feet in length, have been driven just above high-tide level on small mineralized shear zones in greenstone. These two shear zones are about 20 feet apart. The northern one has a maximum width of 2.2 feet, strikes N. 50° E., and dips 75° S. Quartz, epidote, chalcopyrite, and pyrite occur in the crushed and shattered greenstone. The southern shear zone strikes N. 65° E. and dips 60° S. A short distance north of these two tunnels and a little higher is an open cut on an indefinitely delimited area of shattered greenstone, cemented by quartz, pyrite, and epidote. The greenstone is also slightly impregnated with pyrite. At the head of the bay a little open-cut work has been done on a narrow shear zone in greenstone. This zone strikes S. 75° E. and dips 85° N. Pyrite was the only sulphide observed in specimens from this locality.

About 1½ miles south of the head of the bay over a graded trail there are two short tunnels driven in the greenstone ridge at the head of the valley. The lower tunnel, at an elevation of 540 feet, is about 90 feet long, with a 15-foot crosscut. A narrow, poorly defined shear zone is visible in the bluff over the tunnel mouth, but no ore was seen. The other workings, at an elevation of 830 feet, consist of a tunnel about 75 feet in length with a short drift and a winze at the junction of the drift and main tunnel. Both the winze and the drift were full of water in October, 1916. The greenstone country rock is somewhat sheared, but the shear zones are narrow, short, and only slightly mineralized. Quartz, epidote, chlorite, chalcopyrite, pyrrhotite, sphalerite, and pyrite form the ore minerals.

HERRING BAY.

A little development work has been done on Herring Bay on prospects formerly belonging to the Crown Copper Co. The prospects examined are at slight elevations above sea level and only a short distance from the shore. A tunnel 30 feet in length, with a 10-foot drift to the north, has been driven at an elevation of 110 feet in slightly shattered massive greenstone. Epidote stringers occur in the greenstone country rock, but no well-defined vein or shear zone was observed. No ore was found in place in the tunnel, but the few specimens of ore seen on the dump at the mouth of the tunnel contained quartz, epidote, pyrite, pyrrhotite, and chalcopyrite. There are some strippings and open cuts across the south end of a low hill west of this tunnel. The country rock is a shattered greenstone which is slightly mineralized at the western open cut. What ore there was at this locality must have occurred in very small lenses and stringers in the greenstone. None is visible in place now. A few ore specimens found on adjacent dumps contained quartz, pyrite, pyrrhotite (?), sphalerite, and chalcopyrite.

A little farther north on this same ridge is an open cut on shattered and slightly sheared greenstone. The shearing strikes N. 15° W. and dips about 90°. A small amount of sulphides is distributed through a zone which is stripped for a width of about 15 feet and is traceable continuously for about the same distance. The largest sulphide stringer was about 2 inches thick and about 3 feet long. The mineralization is irregular and very slight. Sphalerite, chalcopyrite, and pyrite are the principal sulphides.

LOWER HERRING BAY.

On the east side of the northeast arm of Lower Herring Bay, about halfway to the head of the arm, a short tunnel has been driven on a nearly flat-lying stringer, 1 to 6 inches thick, which cuts the greenstone country rock. Epidote is the predominant gangue mineral, and pyrite is the most abundant sulphide. Only a very little chalcopyrite is present.

BAY OF ISLES.

The development work on the Pandora property, on the Bay of Isles, has been done at an elevation of 380 feet above sea level on the west bank of a small stream that flows into the long southern arm of the bay. On the shore of the bay two cabins have been erected, and a trail extends from that point to the workings, which are below timber line. The surface developments near the ore body include two small sheds and a head frame for a shaft. Some open cuts and strippings have been made on the ore body. The underground work consists of an 85-foot tunnel with two drifts 15 and 20 feet in length, a crosscut 35 feet long, and a shaft sunk to a reported depth of 95 feet. At 9 feet from the bottom of the shaft, it is reported, drifts were opened on the ore for 65 feet in one direction and 45 feet in the other. Crosscuts were also driven short distances into both hanging and foot walls at a depth of about 65 feet and into the hanging wall at the lower level. Twelve or thirteen men were at work on the property early in 1916, but work was discontinued about the middle of June, and the shaft was full of water in September.

The ore deposit consists of several nearly parallel slightly mineralized shear zones in greenstone that incloses large unsheared horses of greenstone, around which the shear zones wrap and meet in strike and dip. The width of the sheared belt is at least 100 feet. The width of the individual shears ranges from 2 to 20 feet. The general strike of the sheared zone is N. 10°–15° W., and the dips recorded on the separate shear zones are 65°–80° E. The ore was formed by replacement and impregnation of the sheared material and as a filling of fissures. Sulphide lenses as much as 15 inches thick were observed, and the shaft is said to have been sunk on 5 feet of good copper ore. The ore minerals are chalcopyrite, chalmersite, pyrrhotite, and quartz.

RUA COVE.

The Copper Bullion claims, forming the Rua property, as it is commonly called, are on the east side of Knight Island about half a mile northwest of Rua Cove, an exposed indentation about midway in the east coast of the island. The workings are below timber line, at elevations of 360 to 750 feet above sea level. A trail leads from the northwest corner of Rua Cove, past a cabin at an elevation of 200 feet, to the entrance of the lower tunnel. Here there is a blacksmith shop. This tunnel, about 365 feet in length, with crosscuts 5, 35, 35, and 60 feet in length, was the only underground work seen on the property. The surface developments consist of numerous open cuts and strippings on the outcrop of the ore body.

The country rock is dominantly greenstone, some of which shows an ellipsoidal structure, but some cherty and quartzitic rocks, possibly of sedimentary origin, occur in the outcrop of the ore body at an elevation of about 700 feet.

The ore body on the Copper Bullion claims appears to be a linked system of mineralized shear zones inclosing large horses of unsheared, unmineralized country rock. The general strike of this system of shear zones is about N. 30° E., and the dip is 55°-75° W. The ore exposures are on a southward-facing mountain slope between elevations of 360 and 750 feet. Above this point beds of massive unmineralized greenstones overlie the ore body. Another ore-bearing outcrop is reported farther north, however, where a creek is said to have cut down through these overlying lavas and exposed a mineralized shear zone. The tunnel at 360 feet above sea level is started on a shattered, slightly iron-stained zone in the greenstone. The first 300 feet of the tunnel contained no ore. A crosscut driven to the east at this point is for its entire length in more or less mineralized greenstone. The 35-foot crosscut to the west at the face of the tunnel crosses a 27-foot ore-bearing shear zone, the western contact of which has a strike of N. 30° E. and a dip of 75° W. At an elevation of 500 feet above tidewater a mineralized shear zone 50 feet in width strikes N. 5°-20° E. and dips 65° E. At an elevation of 540 feet and a little west of this shear zone is another mineralized shear zone which forms a well-marked gulch in the hillside. This zone strikes N. 25° E., dips 60° W., and has a width of several feet. Its hanging wall is massive unmineralized ellipsoidal greenstone. At an elevation of 610 feet the two last-mentioned shear zones join, and the combined zones extend up to an elevation of about 750 feet, where the outcrop pinches out beneath overlying greenstone flows. A trench 90 feet in length has been cut across the outcrop of the ore body at an elevation of about 700 feet. Lenticular masses of country rock are included within this shear zone, but the western 45 feet is nearly solid sulphides, and much of the remaining width is mixed ore and country rock.

Pyrrhotite is the predominant sulphide of the ore body, although some chalcopyrite is always present. Quartz also occurs associated with the sulphides.

DRIER BAY.

JONESY GROUP.

The Jonesy group of claims, at the head of Drier Bay, includes the ore deposit formerly known as the Bald Eagle. Considerable development work, including the erection of wharf, offices, ore bunkers, steam power plant, and aerial tram, was done on this property about 1907.[1] Of these improvements but two log cabins remain. The ore body, on which about 350 feet of underground work has been done, is about half a mile east of the head of the bay, at an elevation of about 1,000 feet. The country rock is greenstone. In the vicinity of the ore deposit a linked system of shear zones has been developed, and narrow bands of green schist wrap around horses of the massive greenstone. A narrow dike of fine-grained dark-colored basic rock has been intruded along one of the larger shear zones. These shear zones are more or less mineralized. The tunnel is driven on a zone of schistose greenstone which strikes N. 15° W. and dips approximately vertically. About 75 feet east of the mouth of the tunnel another shear zone, darker colored and more mineralized, crops out. This zone, which forms the main ore deposit, has been crosscut in the tunnel and opened by drifts for about 100 feet. It strikes N. 15° E. and dips 65° E. The width varies from less than an inch to 8 feet. A winze reported about 20 feet deep has been sunk on this shear zone, and some of the ore in the north drift has been stoped out. Chalcopyrite and pyrrhotite are the ore minerals.

MONARCH CLAIM.

The Monarch claim is about 1½ miles northwest of the head of the northern arm of Drier Bay. A trail leads from the shore to the underground workings, at an elevation of about 700 feet. These workings aggregate about 320 feet in length. No definite ore body was seen underground. The rock on the dump shows a small amount of pyrite and chalcopyrite impregnating a somewhat sheared greenstone. Epidote and quartz were present as gangue minerals. An iron-stained outcrop is reported to occur in the hills above the tunnel, but could not be located.

KNIGHTS ISLAND ALASKA COPPER CO.

The property of the Knights Island Alaska Copper Co. is located on an eastern arm of Drier Bay, known as Northeast Cove and Kiacco Cove. A cabin stands on the northeast shore of the cove, and a trail leads from this point past another cabin in a low saddle 700 feet above sea level to the underground workings one-third mile (in an air line) northeast of the cove, at an elevation of 950 feet. The underground workings consist of a crosscut tunnel about 650 feet in length, three drifts 20, 40, and 60 feet in length, a winze, and a raise. The country rock is greenstone. A very slightly mineralized zone of sheared greenstone, about 55 feet in width, was cut near the inner end of the tunnel, and two drifts were run in it. The winze was sunk on a 5-foot portion, which was somewhat more mineralized than the rest of the zone, and a raise was started above the winze. The outcrop of the ore body lies at an elevation of about 1,200 feet. The sheared belt strikes about N. 15° E. and appears to be traceable for a few hundred feet. The width of the shear zone ranges from 20 to 50 feet, but the walls are very indefinite and the zone includes horses of unsheared greenstone. A fine network of quartz stringers shows in the outcrop of the shear zone. The zone is only slightly mineralized as a whole, but in some places short bunches or lenses of solid or nearly solid sulphides occur in the sheared greenstone. A shallow shaft has been sunk on one lens 7 feet wide composed mostly of sulphides. Another sulphide lens 2 feet thick was observed. The minerals in the ore consist of chalcopyrite, chalmersite, sphalerite, pyrrhotite, and quartz. Basic dikes 1 inch to 12 inches thick and irregular masses of basic igneous rocks cut and intrude the mineralized shear zone.

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[1] Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, pp. 67–68, 1910.

COPPER COIN GROUP.

The Copper Coin group is on the south side of Drier Bay, between Barnes Cove and Mallard Bay, on a prospect formerly the property of the Russell Ball Copper Co. But little development work has been done on the property since it was visited by Grant and Higgins[1] in 1908. A cabin stands near the shore and a trail leads from the cabin to the workings. A wire-rope aerial tram, in operation in 1908, is now out of commission. The underground developments consist of a 60-foot adit, some short crosscut tunnels, and some open cuts. The adit, at an elevation of about 550 feet above sea level, is driven on an iron-stained shear zone in greenstone. This shear zone strikes N. 10° W., dips 70° E., and ranges in width from 10 inches to 10 feet. The widest part of the zone is at the mouth of this tunnel, and here, in the shear, are several lenses of solid sulphides from mere seams to some 6 inches in thickness. A vein of solid sulphides 3 to 12 inches thick lies along the footwall of the shear zone. Considerable quartz is present in the shear zone in places. At 40 feet above the tunnel, in the outcrop of the shear zone, here 8 feet in width, is a quartz lens 32 inches thick. The shear zone extends a considerable distance both up and down hill from the adit tunnel. At its lower end the zone is wider, appears to be less well defined, and contains horses of unsheared greenstone country rock around which the sheared material wraps. The mineralization here is also less concentrated than at the tunnel. The minerals recognized in the ore from this property are chalcopyrite, chalmersite, pyrrhotite, and quartz. Limonite as a surficial product of weathering is present in the outcrop of the ore body.

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[1] Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, p. 68, 1910.

MALLARD GROUP.

The Mallard group of claims is at an elevation of 1,500 feet in a gap at the head of Mallard Bay. The only development work consists of a shallow shaft and some open cuts. The country rock is entirely greenstone. The ore body appears as a large curved shear zone in greenstone with smaller shears wrapping around lenticular horses of massive greenstone along the footwalls of the main zone. This zone makes a marked depression in the gap, and at the time of visit in September, 1916, this depression was filled with snow, so that the major portion of the ore body was not visible. The footwall of the main shear zone, a steep bluff, strikes N. 35° E. at its south end and curves gradually to N. 80° E. at the north end. The dip is 60°–75° W. The exact width of the main shear zone was indeterminate on account of the snow cover but probably does not exceed about 20 feet. The part visible in September, 1916, was along the footwall in the northeastern half of the ore body. The main part of the ore body is said not to have been exposed at the time of visit, but ore carrying 5 per cent of copper is reported in the shaft. The minor shears exposed along the footwall are small and slightly mineralized. The ore minerals seen in specimens collected from this property are epidote, pyrite, chalcopyrite, and quartz. Gold is also reported.

NELLIE GROUP.

The Nellie group of claims is located over a mineralized shear zone that crosses a deep gulch about one-third mile northeast of the head of Drier Bay, at an elevation of about 650 feet. The development work on the property consists of five open cuts, a 6-foot shaft, and a 36-foot adit tunnel. The tunnel is driven northward, on the north bank of a westward-flowing stream, in a mineralized shear zone, which strikes N. 25° E. and dips 75° E. The country rock is greenstone. At the face of the tunnel the shear zone is 9 feet in width. A 12-inch band of sheared greenstone containing a 2-inch lens of solid sulphides lies along the west wall of the shear at the face. The rest of the zone at this point is filled with large lenses of greenstone, around which narrow strips of sheared greenstone wrap. On the south side of the creek the shear zone is about 20 feet wide and consists mostly of solid greenstone, with several layers of chlorite schist

18 inches or less thick. At an elevation of 770 feet on the south side of the gulch the shear zone, here 9 feet in width, is made up largely of a dark schistose mineralized rock. The southernmost exposure of this shear zone is at an elevation of 900 feet, where there was a showing 15 inches wide. On the mountain north of the tunnel the shear zone is traced by scattered outcrops and a few open cuts along its general strike, though it can not be said definitely that these showings are all in the same shear zone. They are not continuous, and in places the shearing is diffuse and the zone contains much massive greenstone and little schistose material. The showings, however, lie in a comparatively narrow belt trending N. 7°–25° E. and traceable for at least three-fourths of a mile. At an elevation of 1,200 feet on the mountain north of the tunnel a 5-foot shaft has been sunk on a 10-foot shear zone in greenstone, the strike of which is N. 7° E. and the dip 70° E. On the crest of the ridge, at an elevation of nearly 1,400 feet above sea level, the shear zone strikes N. 25° E., has a steep easterly dip, and ranges from 4 to 12 feet in width. The mineralization is slight in much of the zone. The minerals present in the ore are chalcopyrite, chalmersite, pyrrhotite, and quartz. Chalmersite was observed only in the shallow shaft.

OTHER PROSPECTS.

Assessment work is reported in 1916 on the U and I group and on the Alhambra group. The total development work on the Alhambra group is reported to consist of two tunnels, 60 and 100 feet in length, and four open cuts.

COPPER BAY.

A tunnel has been driven just above high-tide line on the northeast shore of Copper Bay. Camp buildings have been erected on the shore east of the tunnel. The country rock is a fine-grained dark-green igneous rock. The tunnel is driven in a slightly shattered greenstone in which some of the fractures are healed by epidote stringers or by small quartz veins carrying epidote and sulphides associated with slight sulphidic impregnation of the adjacent country rock. No definite ore body was seen, and little ore could be found either in the tunnel or on the dump. The minerals present in the ore specimens collected include epidote, quartz, calcite, pyrite (?), pyrrhotite, chalcopyrite, and sphalerite.

SNUG HARBOR.

On the north side of the entrance to Snug Harbor a short tunnel crosscuts an ore body which appears to be interbedded with the slate and graywacke. The ore body crops out a short distance west of the tunnel mouth, where it has a width of 2½ feet. The strike is N. 35° E. and the dip 73° W. In the tunnel a slightly more easterly strike and a nearly vertical dip were observed. The maximum width of mineralization is about 5½ feet. In places there are lenses of solid sulphides 12 inches thick. Quartz, sphalerite, chalcopyrite, and pyrrhotite are present in the ore.

MUMMY BAY.

MINNIE CLAIM.

The Minnie claim lies east of the head of the northeast arm of Mummy Bay, at an elevation of 700 feet. An adit 140 feet in length has been driven on a small, slightly mineralized shear zone in a series of slate, graywacke, and intrusive greenstone. Chalcopyrite sphalerite, pyrrhotite, and quartz are the ore minerals. A little secondary native copper appears on the weathered outcrop of the ore body.

HOME CAMP LODE.

The Home Camp lode is at the head of Mummy Bay. Between the shore and an elevation of 75 feet a series of open cuts expose a belt of shearing striking N. 20°-30° E. A shaft about 7 feet deep has been sunk at one point. The maximum width of the mineralized shear zone as stripped is 10 feet, and the ore deposit has been uncovered for about 165 feet. Several small sulphide lenses are scattered through this mineralized zone. The largest lens is 10 feet in length and has a maximum width of 10 inches, pinching out at both ends. The mineralization appears to be confined to sedimentary beds (slate and quartzite?) included in the greenstone. A crosscut tunnel 15 feet in length has been started at a slightly lower elevation and is being driven in a westerly direction to cut this belt of sheared sediments. The face of this tunnel is in black slate, the cleavage of which dips 80° W. The dip of the mineralized shear zone is nearly vertical. Quartz, pyrrhotite, chalcopyrite, sphalerite, and chalmersite constitute the ore minerals.

HOGAN BAY.

The only ore deposit examined in 1916 on Hogan Bay is on the south side of the bay just inside the entrance. A mess house and a bunk house stand on the mountain side at an elevation of about 125 feet above sea level but bear no evidences of recent occupation. A crosscut tunnel between 1,100 and 1,200 feet in length has been driven 40 feet above high tide about 300 feet west of the camp buildings. The country rock is massive-bedded graywacke. This tunnel has apparently not reached the ore body for which it was started, a vein that crops out farther up the mountain to the southeast. At an elevation of 240 feet another tunnel, 260 feet in length, has been driven in a graywacke series into which a little greenstone has been intruded. The bedding near the mouth of the tunnel strikes N. 25° E. and dips 70° W. At 190 feet from the mouth of the tunnel drifts aggregating 105 feet have been driven in both directions on a shattered zone 1 to 4½ feet in width, which strikes N. 30 W. and dips 45° W. A short raise has been carried up on this zone in each drift. The mineralization is confined chiefly to a narrow belt 2 to 8½ inches thick along the footwall of the shattered zone. A short upper tunnel is reported to have been driven at an elevation of 450 feet. About 2 feet of ore is reported in places in the outcrop of the vein. Quartz, chalcopyrite, sphalerite, and pyrrhotite were observed in the ore.

THE GOLD PLACERS OF THE TOLOVANA DISTRICT.

By J. B. Mertie, Jr.

INTRODUCTION.

LOCATION AND EXTENT.

The Tolovana district lies in the northwestern part of the Fairbanks quadrangle, in the headwater region of Tolovana River and Hess Creek. (See Pl. XIII.) At present active mining operations are confined to Livengood Creek, a tributary of Tolovana River entering from the north about 2 miles above the mouth of the West Fork, and to several smaller streams which drain the ridge between Livengood Creek and Tolovana River.

PREVIOUS WORK.

The Yukon-Tanana region was covered by reconnaissance topographic surveys in the years from 1902 to 1910. That portion of the Fairbanks quadrangle under present consideration was mapped topographically in 1907 by D. C. Witherspoon and R. B. Oliver on a scale of 1:250,000, and their map constitutes the base for the present report.

Geologic exploration of the headwater region of Tolovana and Hess rivers by the Geological Survey began in 1904, when L. M. Prindle and F. L. Hess, during a reconnaissance from Eagle to Rampart by way of Fairbanks, carried a geologic traverse across the Tolovana district from northeast to southwest. In 1906 R. W. Stone made another geologic reconnaissance across this district, in going from Circle to Fort Hamlin. In 1909 L. M. Prindle and B. L. Johnson crossed the southern edge of the district, in the course of a geologic reconnaissance from Circle to Rampart by way of Fairbanks. Additional geologic information is also available from the traverses of A. H. Brooks made in 1902 and 1906, both of which passed a short distance south of the Tolovana district.

The principal Survey publications that have a direct bearing on the geology and mineral resources of the Tolovana district are as follows:

Prindle, L. M., and Hess, F. L., The Rampart gold placer region, Alaska: Bull. 280, 1906.

Stone, R. W., A reconnaissance from Circle to Fort Hamlin, Alaska: Bull. 284, pp. 128–131, 1905.

Prindle, L. M., The Fairbanks and Rampart quadrangles, Alaska: Bull. 337, 1908.

Prindle, L. M., Sketch of the geology of the northeastern part of the Fairbanks quadrangle, Alaska: Bull. 442, pp. 203–209, 1910.

Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: Bull. 525, 1913.

Brooks, A. H., Preliminary report on the Tolovana district: Bull. 642, pp. 201–209, 1916.

PRESENT INVESTIGATION.

The present report sets forth the results of a study of the gold placers of Livengood Creek and near-by streams and of the geology and mineral resources of the surrounding territory, here designated the Tolovana district. In all 29 days was devoted to the work, of which 13 days was spent in an examination of the gold-placer mining operations and 16 days in a geologic reconnaissance of the adjoining territory to the north and west. The accompanying map includes an area of 1,835 square miles, about 300 square miles of which was covered by geologic reconnaissance mapping during a part of July, 1916. The geologic data for the remainder of the area were compiled from the work of earlier investigators.

ACKNOWLEDGMENTS.

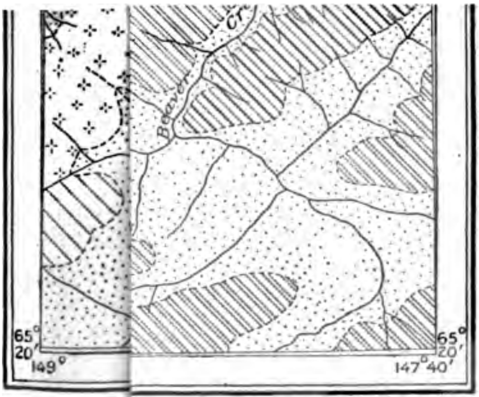
The writer takes this opportunity to thank the operators and prospectors on Livengood Creek and vicinity for their unfailing hospitality and for their willing cooperation in the work. Special thanks are due to Mr. Charles Craig, to whom the writer is indebted for a pleasant home during his sojourn on Livengood Creek, also to Mr. Kelly, who accompanied and materially assisted the writer on a reconnaissance trip to the head of the North Fork of Hess River.

In the investigation and interpretation of the hard-rock geology for the accompanying map, the writer has conferred freely with L. M. Prindle, of the Geological Survey, who has done most of the earlier work in the Yukon-Tanana region; and in the study of the Quaternary history the writer has received a number of helpful suggestions from H. M. Eakin, also of the Survey.

GEOGRAPHY.

RELIEF.

The Tolovana district is a part of the Yukon-Tanana upland. Its topography is characterized by broad, even-topped ridges, which rise to a general elevation of 2,000 feet or higher and from which long, gently sloping spurs descend to the valley floors. The district contains no high mountain groups that rise above the general ridge level, such as the White Mountains, to the east, or the Sawtooth



Geology by J. B. Mertie, jr., L. M. Prindle, and others

Range, to the west. Where the ridges attain an elevation above 2,500 feet, however, there is a marked tendency toward the development of the more precipitous type of mountain topography.

The district is highest in its northern and eastern parts, sloping south and west toward the valley floors of Tolovana and Hess rivers and the lower interstream ridges. The highest locality is in the northeastern corner of the area, where a ridge top rises to an elevation of 3,200 feet. The difference between 3,200 feet and 400 feet, the elevation of the valley floor of Tolovana River below West Fork, represents the maximum relief of this area.

There are a number of elevated prominences in the district, few of which have been named. Two such domes on the ridges north and south of Livengood Creek are known, respectively, as Livengood and Amy domes, and a knoll on the west end of the ridge south of Livengood Creek has been called Money Knob.

DRAINAGE.

Most of the district is drained by Hess and Tolovana rivers, but a minor part, along the eastern edge, lies within the drainage basin of Victoria and Beaver creeks. The watershed between the Yukon River drainage basin, represented by Hess River and Beaver Creek, and the Tanana River drainage basin, represented by the Tolovana, follows an irregular course across the district, owing to the intricate interlocking of these two drainage systems. About two-thirds of the area lies within the Yukon basin. (See fig. 5.)

The present streams are sluggish and meandering, and the water is universally more or less amber colored. Within the hilly areas there is more or less iron-stained gravel in the stream beds, although the gradients are low and the streams are in many places incised between steeply cut silt banks. In places well-developed gravel bars are present, but these appear to be only blanket deposits over fine silty sediments. The impression gained from these bars is that the gravel is transported largely from the extreme headwaters at stages of high water. In their lower courses the larger streams meander over wide alluvium-filled flood plains to the Yukon and the Tanana. In both the headwaters and the lower courses of the several drainage systems the present streams are markedly disproportionate to their valleys, for the valleys are wide and show the effects of vigorous erosion, whereas the streams are sluggish and carry relatively little water. It is apparent that the present streams are the feeble descendants of an earlier and more active drainage system.

Adequate corroborative evidence of the former presence of a drainage system of different character is afforded by topographic features unrelated to present streams, such as high rock-cut benches, by physiographic anomalies of the present drainage, such as broad alluvium-filled valleys, certain higher-level alluvial flats, and low alluvium-filled interstream divides, and by what is known of the bedrock cross sections of the present valleys, as revealed by placer-mining operations.

It is worthy of note that many of the streams in the eastern half of this area flow in general northeast or southwest directions. This feature is evidently in conformity with and a result of the structural trend of the rock formations. West of 148° 20′ west longitude, however, there is a marked tendency toward the development of east or west courses in the streams. This is exemplified by Tolovana River west of the mouth of Bridge Creek, by Hess River west of the forks, and to a lesser degree by Livengood Creek. This change is the physiographic expression of a change in the regional trend of the rocks, comparable with a similar change noted by Prindle[1] in the Troublesome Creek area, to the west.

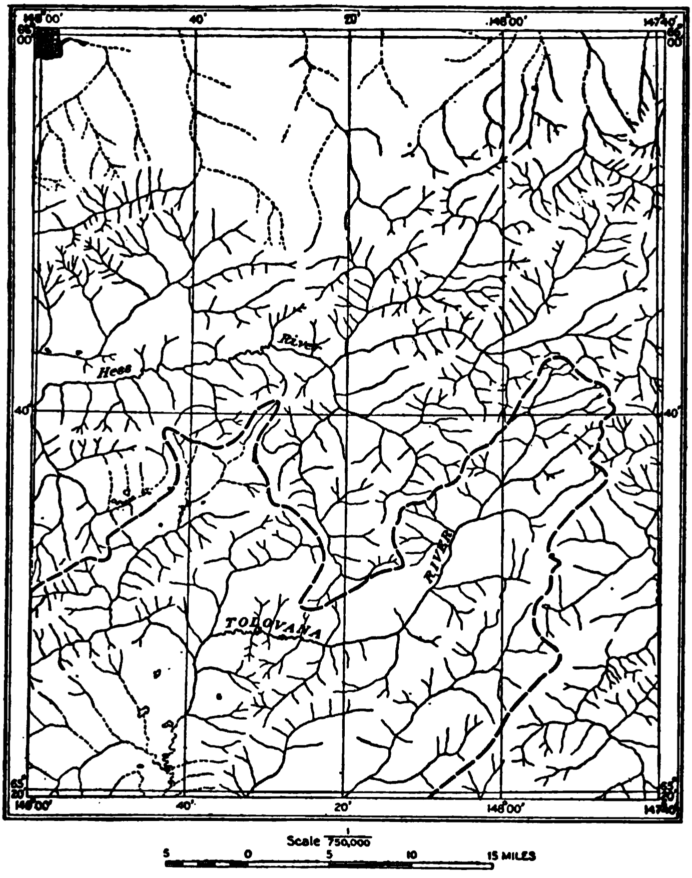


Figure 5.—Sketch map showing watershed between Yukon and Tanana drainage basins.

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[1] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, p. 55, 1913.

The lower course of Tolovana River, though beyond the limits of the area under discussion, is worthy of separate mention, partly because it is the main approach by water to Livengood and also because the lower and upper courses really constitute a single physiographic unit. A traverse of the lower 110 miles of Tolovana River was made by the writer in a gasoline scow by the time and compass method.

The Tolovana flows in a tortuous meandering course through a broad, flat alluvium-filled valley, which, in its lower part, merges with the valley of the Chatanika, a tributary of the Tolovana from the southeast about 74 miles above its mouth. At the junction the Chatanika is much the larger stream of the two, carrying the combined flow of Tatalina River and Goldstream Creek. The Tatalina does not flow into the Tolovana, as indicated on the earlier maps, but enters Chatanika River 3 miles above the confluence of that stream with the Tolovana.

The only straight stretch of any great length in the Tolovana begins at a point about 62 miles from the Tanana and extends northeastward for 3 miles. Elsewhere the river consists of a continuous series of loops and oxbows, which above the mouth of Chatanika River become more numerous but of smaller amplitude. One of the peculiarities of the river's course is the wide sweep which it makes above the mouth of the Chatanika, extending up into the embayment at the mouth of Uncle Sam Creek and returning across the valley to the southeast side. For 90 miles above its confluence with the Tanana the Tolovana hugs the northwest side of its valley, approaching closely to the hills at several localities. In this stretch and for 10 or 15 miles farther the river is sluggish, except at the mouth of Chatanika River, where there is a decided current. This sluggishness is particularly marked for a distance of about 25 miles above the mouth of the Chatanika, where even in the narrowest parts of the stream it is often difficult to detect the direction of flow. The river appears to be very deep in such sluggish channels. From this point up to the log jam the current is more apparent, the river flowing over a bottom composed largely of interlacing waterlogged trees. At low stages of water this is a very difficult stretch of the river to navigate.

Except where the Tolovana sweeps close to the hills the banks consist entirely of silt and sand and increase in height from a few feet at the Tanana to 50 feet in the vicinity of the log jam at low water. The alluvium appears to be almost entirely silt above the Chatanika. The upper course of the Tolovana, from the log jam to West Fork, was not traversed, but it is reported that the silt banks decrease in height above the log jam, ending a short distance below Trappers Cabin, where sand and gravel bars begin that continue upstream.

TOPOGRAPHIC ANOMALIES.

The topography of Livengood Creek and vicinity shows certain anomalous features worthy of special mention. Livengood Creek, the South Fork of Hess River, and most of the other streams in the vicinity are small in comparison to the wide alluvium-filled valleys in which they flow. The stream gradients are low, except in the extreme headwaters, and the transportation of rock débris is relatively small except at high stages of water. This marked disproportion seems to indicate a lack of adjustment between the topography and the present streams and points to an earlier period of erosion, more active than that of the present.

Several low divides that are distinctly anomalous in character and position separate the headwaters of several of the streams in this area. Thus a low, broad, flat timber-covered divide separates the head of Livengood Creek from the South Fork of Hess River. At the northwest end of this divide, at the head of Snow Gulch, a tributary of the South Fork, a prospect shaft was sunk 205 feet through muck and slide to the chert bedrock. As the difference in elevation between the top of this shaft and the present level of the South Fork of Hess River, at the mouth of Alabam Creek, is but 95 feet, the shaft shows that the northwest end of this saddle, at least, is composed entirely of unconsolidated material, which continues downward to a depth of about 110 feet below the present level of the South Fork; and it seems highly probable that this is the general make-up of this divide as a whole.

At the heads of Pedro, Lost, and Erickson creeks there is a timber-covered flat from 2 to 4 miles wide, at an elevation of about 1,000 feet. McHugh and Myrtle creeks are separated from this wide flat and its included drainage systems by only slightly higher divides that approximate 1,200 feet in elevation. Data on the terranes which constitute these low divides may be obtained only by shafts or drill holes, but it is highly probable that they are likewise composed, to a greater or less depth, of muck and slide similar to the material at the head of Livengood Creek.

Numerous facts indicate that extensive changes in drainage have taken place. In addition to the alluvium-filled saddles there are many well-developed instances of backhand drainage; numerous lakes occur in the low alluvium-filled divides and on alluvium-covered spurs; and along some of the present streams there are constricted portions that approximate gorges in character. Old erosional channels in bedrock benches along the sides of and unrelated to the present streams likewise give ample evidence of the lateral migration of erosional channels within certain stream valleys, induced probably in part by major drainage changes.

The West Fork of the Tolovana affords the best example of backhand drainage on a large scale in this district. This stream runs 32 miles in a general northeasterly direction from its source, and then turns abruptly to join the main Tolovana, which flows in a general southwesterly direction to Tanana River. The valley of Lost Creek seems to be the logical continuation of the valley of the West Fork, with a possible outlet by way of Erickson or Pedro Creek to Hess River; but without a more detailed study of these creeks, a more definite statement can not be made. Another excellent example of backhand drainage is the stream that enters Tolovana River on the west side about 7 miles below the West Fork. This stream also flows northeastward to empty into the southwestward-flowing Tolovana. A low alluvium-filled saddle at an elevation of about 1,200 feet separates the head of this creek from Idaho Creek, to the southwest. Drainage changes are likewise evident at the heads of Erickson, Lost, Pedro, and Livengood creeks. (See pp. 260–262.) It is perhaps highly significant that many of the most pronounced drainage changes are localized at or near the low saddles previously described.

Lakes are numerous in the alluvium-filled valleys, on the low interstream divides, and even on some of the alluvium-covered spurs that descend from the ridges to the valley floors. The lakes in the lower valleys are probably due in large part to processes connected with stream aggradation; but some of these, as well as the high-level lakes on the divides and spurs, indicate a condition of imperfect adjustment to recent changes in drainage. The high-level lakes in particular, such as the group at the heads of Erickson and Lost creeks, give no indication from their form or character that they have ever been a part of any drainage system. In addition to the lakes shown on the map, there are scores of smaller lakes of similar character, hidden in the timber, which are not visible from the ridges and are seen only by accidental visit. Thus on the timber-covered spur between Amy and Goldstream creeks, a short distance above the head of Goodluck Creek, there is a small lake, filled with amber-colored water, which appears to be a watering place for game.

Another such lake, on the flat spur northeast of Patterson Creek, is 500 feet in diameter, is more or less circular in shape, and has steep muck walls about 40 feet high. The water is deep, a depth of 8 feet being attained only a few feet from shore. The elevation of this lake is about 1,100 feet, or about 140 feet above the level of the South Fork of Hess River, at the mouth of Patterson Creek. On the northwest side there is a gap in the silt walls, where the banks are only a little higher than the lake itself. Although no water was flowing from the lake through this gap when it was visited, there is a drainage channel which connects the gap with the South Fork of Hess River. It is probable that this lake was at one time still deeper than at present, possibly as much as 30 or 40 feet deeper, and that the gap at its northwest end represents a break in its walls, due to the general reduction in elevation of the spur below it through erosion by Hess River. In this manner the lake was reduced to its present level, and the continuation of the same process would ultimately drain it.

As indicating readjustments in drainage the presence of a gorge along the course of a stream, with a wide, open valley above and below, may be of significance. Such gorges are reported from several localities, but the only one visited by the writer is in the valley of the South Fork of Hess River about 4 miles below the mouth of Alabam Creek. This gorge is a late feature in the history of the South Fork, for it is in the bottom of the valley and is not apparent from the ridges on the sides.

Readjustments of stream courses within their own valleys are plainly apparent from the presence of old channels cut in bedrock benches above many of the present streams. Such benches are locally visible but in many places are covered by later alluvium and would not be suspected from the present cross sections of the valleys. Thus on Livengood Creek above Livengood there is an old stream channel on the north side of the valley, separated from the present stream by a bedrock reef that crops out at Livengood. Upstream both the reef and the old channel are concealed by a heavy mantle of silt. Placer-mining operations, however, have shown that this reef continues upstream for 3 miles, and above its termination the old channel and the present stream channel gradually merge into each other. It is this old channel in the valley of Livengood Creek that carries the auriferous gravels now being mined.

On the South Fork of Hess River there is likewise evidence that the present course of the stream is quite different from its course during a preceding physiographic cycle. Placer operations have not yet been extensive enough to show definitely the location of the old channel, but the available data indicate that it may have been on one side of the valley at one locality and on the other side at another thus being crossed and recrossed by the present stream.

Remnants of high rock-cut benches are present in some of the present stream valleys. Thus at the lower end of Livengood Creek, on the spur west of Ruth Creek, there are rock-cut benches at elevations of 1,115, 1,150, and 1,200 feet. The lowest of these benches is only 75 feet wide, but each of the others extends backward toward the main ridge for several hundred feet, and the highest rises gradually to an elevation of 1,300 feet. South of the highest bench the ridge rises rather steeply toward Money Knob, the west end of the ridge between Livengood Creek and Tolovana River. There are fragmentary benches of similar character on other spurs descending to Livengood Creek, but these are not susceptible of coordination without detailed topographic mapping. It is uncertain whether such high benches are the remains of old stream channels, or whether they may represent in part old beach lines correlative with various stages in a regional inundation.

Higher flats at elevations from 1,200 to 3,000 feet are present but can not be correlated and are probably due to various agencies. The ridge tops in the Yukon-Tanana region as a whole are probably the dissected remnants of an old peneplain, in the widest sense of that term—that is, an old erosional surface, more or less uniform in elevation but sloping shieldlike to the major drainage channels. The higher prominences may be thought of as monadnocks upon such a surface. The high flats, however, occur at all elevations and are developed probably in part by normal stream erosion and in part by certain erosional processes that are particularly effective in subarctic climates, including solifluction in its various phases.

SETTLEMENTS AND POPULATION.

Livengood, the principal settlement within the district, is on the north side of Livengood Creek about 5 miles above the mouth of the creek, at an elevation of 625 feet. It is a well-placed and substantially built town, with a post office, a wireless station, and a local telephone system connecting with the mining plants on Livengood Creek.

At the junction of the West Fork with the main Tolovana a small settlement called West Fork has grown up. It is essentially a supply point for Livengood, being at the head of navigation for small boats on the Tolovana. It contains a sawmill, a roadhouse, and warehouses.

There are warehouses also at a place called Trappers Cabin, 16 miles downstream from West Fork, at the head of navigation for launches and small scows.

The log jam, 56 miles by river below West Fork, is another stopping point on the river route to Livengood. It is the head of navigation for small steamboats and gasoline scows and is therefore the principal changing point for passengers and freight along the river. Two roadhouses and several small cabins are located there.

CLIMATE AND VEGETATION.

The Tolovana district is a small part of the Fairbanks quadrangle, whose vegetation and climatic conditions have been described at some length by Prindle.[1] There are no exceptional features of the plant life in the district which warrant any further description, and no new meteorologic data for the district are at hand. For those who are familiar with interior Alaska, it suffices to say that this district is an integral part of the Yukon-Tanana province.

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[1] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pp. 23-28, 1913.

GEOLOGY.

GENERAL FEATURES.

The present geologic knowledge of the Fairbanks quadrangle is based largely on reconnaissance traverses, most of which were made prior to the publication of the reconnaissance topographic map. Hence the knowledge of the stratigraphy is at best fragmentary. It happens also that the new placer camp at Livengood and much of the adjacent headwater region of Tolovana and Hess rivers lies within an area concerning which information was exceptionally meager. The work of 1916 in this area, though likewise reconnaissance in nature, adds new data to the existing geologic knowledge and serves in some measure to coordinate the earlier data.

Several mappable groups of hard-rock formations are present in the Tolovana district. These include the Tatalina group, of Cambrian or pre-Cambrian age; the Devonian and Silurian (?) sequence; a new stratigraphic unit of chert, of Devonian or Carboniferous age; and the Carboniferous sequence of sandstone, slate. shale. and argillite. (See Pl. XIII.)

These rock groups occur chiefly as belts, crossing the district in a general northeasterly direction. The oldest rocks occur to the southeast, and the younger rocks crop out successively to the northwest. The regional trend of the rocks is northeast, and the dips where observed are isoclinal to the southeast. Hence the younger formations dip under the older ones, with the result that a sequence of folds overturned to the northwest is necessary to explain the structure. This explanation, however, is a very generalized induction, and further study may reveal structural details quite at variance with it. A zone of faulting is believed to be present along the northwest side of the chert formation.

Igneous rocks of numerous types are present, though only in the northwestern part of the district do they occupy any large area. They include chiefly basic rocks of various ages, some extrusive and some intrusive. Granitic and intermediate rocks are present in small amounts, the former connected genetically with the mineralization in the vicinity of Livengood.

The hard-rock formations are overlain in the stream valleys by a mantle of unconsolidated deposits, representative of several physiographic eras in the Quaternary. These are the youngest deposits in the region but are not all of the same age. At least two types are recognizable—the present stream deposits and the earlier stream deposits, now forming benches along the present streams. Numerous changes of drainage courses and other data indicate a most complex physiographic history during Pleistocene and Recent time

TATALINA GROUP (CAMBRIAN OR PRE-CAMBRIAN).

DISTRIBUTION AND CHARACTER.

The Tatalina group crosses the southeast corner of the Tolovana district, but little is known of its northwestern limit or of its lithologic character in that locality. The following general description of the Tatalina group is taken from the report of Prindle:[1]

> The Tatalina group can be defined as an aggregate of feldspathic fragmental rocks, including conglomerates, sandstones, and graywackes, interbedded with argillites that are in places altered to phyllites. With these rocks occurs considerable chert. As mapped, the Tatalina includes some limestone, which may or may not represent an integral part of the group. In the White Mountain region the Tatalina group includes considerable greenstone in the form of ancient tuffs and lavas.

The only specific reference by Prindle to the lithologic character of the Tatalina group in the area under discussion is this: "In the west-central part of the quadrangle the group is represented by graywacke, feldspathic conglomerates, phyllites, and cherts."

AGE.

The recent work of Blackwelder[2] has thrown considerable light on the age of the Tatalina group. His stratigraphic work in the White Mountains has shown that the Tatalina group underlies fossiliferous sediments of Upper Cambrian or Lower Ordovician age. Hence the latest information would indicate that the Tatalina group is Cambrian or possibly pre-Cambrian.

DEVONIAN AND SILURIAN (?) ROCKS.

AREAL DISTRIBUTION.

A group of sedimentary rocks with associated igneous rocks, here assigned in part to the Middle Devonian, crop out in a belt crossing the southeastern part of the Tolovana district. It is necessary to separate this group of rocks from the Tatalina group on the basis of lithologic character, and as the lithology of both these groups is only imperfectly understood, the boundary between them, as shown on the accompanying geologic map (Pl. XIII), should be regarded as a suggestion rather than a definite mapping of the contact.

Still farther southeast, within the area mapped as Tatalina, limestone of known Devonian age is present in a narrow disconnected zone, which trends parallel with the regional strike.

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[1] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pp. 37-38, 1913.

[2] Blackwelder, Eliot, Geology of the northern part of the Yukon-Tanana region: U. S. Geol. Survey Bull. — (in preparation).

In the east-central part of the district beds at an unrecognized horizon in the Devonian or Silurian (?) are mapped. They occupy a more or less wedge-shaped area, which begins with the limestone on the South Fork of Hess River at the mouth of Pedro Creek and extends in a widening zone to the northeast. The southwestern continuation of this zone is represented by the limestone at the head of Erickson Creek.

LITHOLOGY.

The Tonzona group, one of the geologic units recognized in the Fairbanks quadrangle, was described originally by Brooks[1] from its occurrence along the inland front of the Alaska Range and along the lower Tanana. His summarized description was as follows:

> A series of argillites, in part interbedded with graywacke and associated with cherts, is here classed together under the name Tonzona group. The Tonzona group has at least one striking difference from the older Tatina group in its marked lack of limestone. It is made up of sediments which, as a rule, are coarser grained than those of the Tatina, being derived chiefly from clays and sands. It includes, however, considerable masses of chert.
>
> The argillites, which predominate in this group, vary from shales to slates and phyllites. One of their characteristic features consists in their variegated colors, which include black, red, green, and blue. Fragmental rocks are represented by gray indurated feldspathic sandstone or graywacke, some of which in the field was mistaken for igneous rock. The cherts, which occur in association with the fine-grained argillites, are also varied in color, including black, greenish-white, green, and red varieties.
>
> The facts in hand suggest that the Tonzona group may be divisible into two members (1) a lower, made up largely of bluish phyllites and black slates, some interbedded with massive graywacke, with which are also associated some black cherts, and (2) an upper, which is dominatingly made of black, red, and green slates, locally grading into shales and cherts of various colors.

On the basis of lithologic similarity, certain Devonian and associated rocks in the Fairbanks quadrangle were tentatively correlated with the Tonzona group, the name being used as a cartographic designation. Prindle's description of these rocks[2] was as follows:

> A series of red, green, and black argillites, conglomerate, and sandstone, including some chert, is here correlated with the Tonzona group. Locally some limestones are included in the Tonzona as mapped. In the area mapped by Stone in the northeastern part of the quadrangle the rocks correlated with the Tonzona are made up of rather coarse conglomerates with sandstones and slates of various colors. On the Tanana the group is represented by fine quartz conglomerates, sandstones, and red and green slates.

Sufficient data were collected in the Tolovana district during the season of 1916 to justify a separation of the Tonzona group into two major divisions. The upper of these divisions, described later as chert, is a fairly definite lithologic unit; the lower division, comprising undifferentiated Devonian and Silurian(?) rocks, must be regarded only as a temporary grouping, which is likely to undergo further subdivision with the accumulation of more detailed information.

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[1] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 73, 1911.

[2] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pp. 44-45, 1913.

As mapped, this lower division includes all the rocks from the Middle Devonian to the Tatalina group. That part of the geologic section between Tolovana and Tatalina rivers has not been studied in any detail and may include Lower Devonian, Silurian, or Cambrian rocks, as well as small areas of infolded younger rocks.

The limestone of known and inferred Devonian age is mapped as a separate unit.

The best exposures of the Middle Devonian rocks are to be seen in the creeks, where placer-mining operations have bared the bedrock. Near the lower end of Ruth Creek, and presumably near the top of the Middle Devonian sequence, there is a black, finely crystalline limestone, much seamed with calcite and quartz. Farther upstream and lower in the geologic column the bedrock for a mile is in part sandstone, shale, slate, and limestone. On claim 4 above Discovery, Ruth Creek, about 1¼ miles above the mouth of the creek, Middle Devonian fossils were found in some finely crystalline dark-gray limestone. The spur on the west side of Ruth Creek shows a variety of rock talus, including sandstone, shale, flint, conglomerate, and serpentine and other igneous rocks. The gravels in Ruth Creek are subangular and at the lower end of the creek comprise chert conglomerate, chert, sandy shale, dioritic material, and other rocks, showing that they were derived from the bedrock of Ruth Creek. Serpentine occurs at the mouth of Ruth Creek and is also exposed at the town site of Livengood, opposite the mouth of Ruth Creek. It is possible that the serpentine forms a continuous body across the valley floor of Livengood Creek at this point, separating the known Middle Devonian rocks from the chert formation. The traverse of Prindle and Johnson (1909) shows that this mass of serpentine continues southwestward along the ridge south of the West Fork of Tolovana River for at least 12 miles.

The sedimentary rocks exposed along the ridge at the head of Ruth Creek consist of dark-colored sandstone, shale, slate, quartzite, and finely crystalline dark-gray to light-gray limestone. The knob at the heads of the East Fork of Gertrude Creek and Ester Creek is a much brecciated chert, which, however, belongs probably in the chert formation.

At the west end of the ridge, near the head of Lillian Creek, placer-mining operations have exposed the bedrock in the creek. It consists of dark-gray sandstone and shale, with some slate. A hundred yards downstream the bedrock is dominantly a dark-colored shale. The respective strikes at these localities are N. 65° W. and N. 45° W., and the dip in each place is 55° N. Subangular to angular stream gravels show the presence near by of chert conglomerate, greenstone, sandstone, shale, slate, and quartzite.

On the south side of the ridge on Discovery claim in Olive Creek, about 1½ miles from the crest of the ridge, the bedrock in the creek is a dark impure sandstone. Here the stream gravels consist of black chert, argillite, hard shale, coarse-grained granitic rock, diabase, green flinty mineralized rock, and chert conglomerate, all representative of the rock formation on the south side of the ridge. Limestone bedrock is also reported from a prospect shaft in this vicinity. About a mile to the east, however, placer mining on Ester Creek has exposed bedrock that is dominantly chert.

At the mouth of Gertrude Creek the bedrock is a brecciated flint, which appears to continue upstream, being present in the East Fork of Gertrude Creek, in association with a white silicified limestone. It is likely that the chert continues up Gertrude Creek to the knob at the head of its East Fork.

The bedrock in the beds of Amy and Goodluck creeks is reported to be largely chert, from which it appears that the Middle Devonian beds are not present in these creeks. Certain basic andesites north of Amy Dome, lying between the Middle Devonian rocks and the chert formation, and a basic rock of similar appearance on the ridge at the head of Cleary Creek are not correlative with the serpentine at the mouth of Ruth Creek. They do not possess a greenstone habit and are thought to be intrusives belonging to a later period of volcanism.

At a point 20 miles N. 63° E. from Amy Dome the serpentine and basic igneous rock previously described reappear, as shown by the traverses of Prindle and Hess (1904) and of Stone (1906). The notes from both these traverses agree in describing the country rock at this locality as a serpentine cut by diabase dikes. Southeast of this serpentine area toward Beaver Creek, Stone's traverse shows the country rock to be black shale, grit, and sandstone, with one recorded strike of N. 64° E. and dip of 18° SE. The traverse of Prindle and Hess shows that the country rock south of the serpentine is conglomerate and black slate. These sediments seem to represent the same horizon as that of the beds exposed in Ruth Creek and on the ridge south of Livengood Creek. The traverse of Prindle and Hess also shows another area of serpentine, cut by diabase dikes, about 13 miles N. 53° E. of the one just described, just beyond the Tolovana. This demonstrates the persistence of the serpentine, but its ultimate northeastward continuation is unknown.

These intermittent occurrences of serpentine and locally of a basic igneous rock of greenstone habit, at or near the upper part of the Middle Devonian beds, seem to be a feature of regional significance. Serpentine and greenstone, however, are represented at other horizons in the Devonian sequence, a fact which has been recognized both by Prindle[1] and by Brooks.[2] The recent work of Blackwelder[3] in the White Mountains has also shown that the limestone on the spur just northwest of the forks of Willow Creek is Devonian and is intimately associated with greenstone. Further work may show that this extrusion of basic igneous rocks attained a maximum development late in the Middle Devonian epoch, thus establishing a reliable horizon marker in the Devonian sequence.

Limestone of supposed Devonian age, similar in appearance to that on Ruth Creek, occurs along the South Fork of Hess River, opposite the mouth of Pedro Creek. It is black and crops out in thin beds, which are broken, veined with calcite, and coated with some white salt of calcium. These beds extend upstream for 500 yards or more, becoming thicker and arenaceous. Still farther upstream is the chert formation. The attitude of these limestone beds, measured at two places, was N. 55° W., dip 75° SW., and N. 55° E., dip 35° SE. This discordance in strike and dip, together with the broken and veined appearance of the beds, is taken as evidence that the rocks at this locality have been greatly disturbed.

At the heads of Grouse and Bear creeks limestones thought to be of Devonian or Silurian age crop out. They are associated with sandstone, shale, slate, quartzite, conglomerate, and chert, the whole representing an unrecognized horizon in the Devonian or Silurian (?). The ridge northwest of Crater Creek is composed of sandstone and shale. Stone,[4] on the basis of the lithologic similarity of certain beds of black shale found just below the confluence of Grouse, Bear, and Crater creeks, included the rocks at this locality as a part of the Carboniferous. As there is no fossil evidence for this assignment, and as the strike of the Carboniferous rocks carries them northwest of this locality, this ridge is here mapped tentatively as a part of the Devonian and Silurian (?) sequence. On the basis of lithographic character, then, a wedge-shaped belt of rock of Devonian or Silurian (?) age is mapped, beginning at the limestone locality on the South Fork of Hess River and extending in a widening zone to the northeast. Necessarily the boundaries of such a zone can not be considered final, and internal differentiation of this zone into smaller units is ultimately certain.

A supposed zone of faulting lies southeast of this zone, and along its continuation to the southwest occur the limestones on the South Fork of Hess River and at the head of Erickson Creek. Little is known of the rock at the latter locality, but the 1904 traverse of Prindle and Hess show the limestone to be brecciated gray crystalline variety. Of special significance is its brecciated condition, in connection with its position along an inferred zone of faulting.

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[1] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, p. 57, 1913.

[2] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 116, 1911.

[3] Blackwelder, Eliot, Geology of the northern part of the Yukon-Tanana region: U. S. Geol. Survey Bull. — (in preparation).

[4] Stone, R. W., unpublished notes, 1906.

The limestones at the head of Bear and Grouse creeks seem similar in general character to those at the two localities, just described. Stone,[1] recognizes two different types of limestone, "one of which is white or gray, whether fresh or weathered, shows no distinguishable bedding, is crystalline, finely jointed, and occurs in conspicuous ledges, and the other is gray to blue on the outside, dark blue inside, thin bedded, and weathers with a rough prickly surface." The former corresponds closely to the Ordovician and Silurian limestone of the White Mountains; the latter is comparable with Middle Devonian limestone recognized in the vicinity of Livengood. The traverse of Prindle and Hess (1904) shows considerable limestone of the latter type along the ridge northwest of Bear Creek, interbedded with red and green shale, quartzite, and greenstone. Measurements of strike taken on this limestone by Prindle and Hess are N. 60° E., N. 55° E., N. 76° E., and N. 59° E., which yield an average of about N. 62° E. for the strike of the rocks in this vicinity. The dips are steep to the south. It is probable that this occurrence, 22 miles N. 60° E. from the Hess River locality, is a continuation of the bed at the same general horizon.

It appears that this limestone is not continuous, for a traverse by the writer down the east side of Butte and Crater creeks, and up into the ridge northwest of Crater Creek, as well as the traverse of Stone in 1906, failed to reveal the presence of limestone in this vicinity along the regional strike. This lack is more probably due to structural irregularities than to original nondeposition. It is worthy of emphasis, as bearing on the regional trend of the Paleozoic rocks, that the direction connecting the limestone on the South Fork of Hess River with that at the head of Bear Creek—that is, N. 60° E.—is nearly identical with that connecting the greenstone locality at Amy Dome with that southwest of Beaver Creek, which is N. 63° E.

The writer is unfamiliar with the limestone areas in the southeastern part of the Tolovana district, within the area of Tatalina rocks. They have been intersected by only one traverse, and little is known of them. In the sharp bend of Fossil Creek at its lower end, just east of this district, on the spur to the northeast, Prindle and Hess found fossils of Middle Devonian age and others suggesting a late Silurian age. It is probable that the limestones above mentioned are representatives of the same general horizon, infolded or infaulted into the Tatalina group.

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[1] Stone, R. W., unpublished notes, 1906.

IGNEOUS ROCKS.

A variety of igneous rocks are present in the Middle Devonian sequence. It is possible, however, to divide them into two groups, which are mutually exclusive, both in age and in their relation to the associated sedimentary rocks.

Basic igneous rocks, in part serpentine, occur between the Middle Devonian rocks and the chert formation, as well as within the Devonian sequence. Presumably these basic rocks are in large part the altered representatives of basic lava flows, which were extruded more or less synchronously with the deposition of the Devonian rocks. It is probable that these lavas represent intermittent volcanism during Devonian time, culminating at the end of the Middle Devonian.

The igneous rocks of the second group are in large part intrusive. At least some of them are undoubtedly later than the Middle Devonian sequence, but the data available are not sufficient to determine their absolute age. They include granitic, dioritic, and basic types. On the ridge south of Livengood Creek occur intrusives of several types, including albite granite, soda rhyolite, diorite, pyroxene andesite, diabase, and basalt. These rocks were certainly not all intruded simultaneously but represent various stages, perhaps even widely separated epochs, in the igneous history of the region. The sodic rocks, including the albite granite, the soda rhyolite, and the pyroxene andesite, seem to have a certain family relationship. The most acidic types are thought to be closely related to the gold mineralization on this ridge.

STRUCTURAL RELATIONS.

Opportunities for the observation of structural details in the Tolovana district are meager, owing to the dearth of outcrops, and trustworthy generalizations can not be drawn from fragmentary data. The few strikes recorded, however, clearly indicate a regional trend of about N. 60° E. for the Devonian sequence. The observations on the dip of the bedding indicate a general dip to the southeast, but there are wide variations in the degree of dip.

Of special interest is the marked change in direction of the contact between the Middle Devonian beds and the chert formation, on the ridge south of Livengood Creek. For a distance of 3 or 4 miles the contact runs northwest, resulting in a marked offset of the contact line. This structural feature is reflected to a lesser degree in the course of Tolovana River, which for 6 miles or more runs slightly north of west, instead of southeast. Along Lillian Creek also the dip of the rocks is to the northeast, instead of to the southeast, indicating local structural changes. The elongation of the silicified limestone bodies within the chert in the valley of Livengood Creek reflects this change. Finally, the localization of the auriferous mineralization in this vicinity is significant. Evidently the ridge south of Livengood Creek is the locus of some major structural feature, but whether it is to be interpreted as a zone of faulting or whether it represents merely a flexure in the regional structure has not been determined.

The interpretation of the regional structure involves the conception of dynamic thrusts and appressed and overturned folds. Under such conditions, particularly with the present indefinite ideas of the limits of the Paleozoic formations, any estimate of thickness is useless.

AGE AND CORRELATION.

The only fossils from the Devonian-Silurian (?) sequence so far collected in the Tolovana district are a small collection made by the writer during the summer of 1916. They were found in pieces of bedrock taken from the bottom of a prospect shaft in the stream gravels of Ruth Creek. The fossiliferous rock is a very dark gray crystalline limestone. The report of Edwin Kirk, paleontologist, on these fossils is as follows:

> East fork of Ruth Creek, a tributary of Livengood Creek, about 1½ miles south of Livengood:
>
> Atrypa reticularis (Linné) var.
> Camarotoechia sp.
> Cyathophyllum caespitosum Goldfuss.
>
> These fossils are clearly of Middle Devonian age.

The fossiliferous limestone is interbedded with shale and sandstone, and the rocks intervening between this fossil locality and the chert formation are similar in character and appearance. It is believed, therefore, that Middle Devonian rocks adjoin the chert, although this statement is not susceptible of proof at present.

While it is therefore apparent that the upper part of the group mapped in this report is Middle Devonian yet any generalization regarding the rocks lying to the southeast between the known Middle Devonian beds and the Tatalina group would be both futile and premature. The northwestern limit of the Tatalina group is unknown, and hence the southeastern limit of the group of rocks under discussion is doubtful to a corresponding degree. Stratigraphic data are meager, and paleontologic evidence is lacking. Recent geologic work in the White Mountains by Blackwelder[1] has shown the presence of new stratigraphic units in the Paleozoic of this region, and it is certain that the geologic groups heretofore used will ultimately be subdivided, and new formations will be defined. Blackwelder's data indicate that the Tatalina group may be either Cambrian or pre-Cambrian. Therefore this group, of Middle Devonian age in its upper part, is assigned tentatively to the Devonian and questionably in part to the Silurian. It may even include Cambrian rocks.

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[1] Blackwelder, Eliot, op. cit.

The regional strike of these rocks would suggest their continuance to the northeast, in the valley of Beaver Creek. Blackwelder describes a "black slate and graywacke group" in that valley, which in the absence of fossil evidence he assigns tentatively to the Mesozoic. These rocks include slates, graywacke, quartzite, conglomerate composed largely of chert and slate, and certain rocks of pyrito-dolomitic character. It is not improbable that these rocks of the Beaver Creek valley may eventually be shown to belong to the Paleozoic and to be, at least in part, correlative with the Devonian rocks.

CHERT.

AREAL DISTRIBUTION.

A stratigraphic series consisting dominantly of chert crops out in a belt crossing the district in a general direction approximating N. 60° E. The southeastern limit of this belt is fairly well defined, but an inferred fault zone along the northwest side of the belt renders its exact delimitation impracticable at present. This chert series forms the bedrock on Livengood Creek and most of its tributaries.

Northwest of the known Carboniferous beds other rocks of dominantly cherty character occur, but the relation between the two groups is obscure. A contact line has been drawn by the writer, but it is based purely on lithologic data and must therefore be regarded only as tentative. It is possible that these cherty rocks represent the upper part of the chert formation.

LITHOLOGY.

The chert series consists dominantly of chert, associated with a minor proportion of other rocks, which include chiefly silicified limestone and argillaceous rocks. Numerous small intrusive bodies of greenstone are also present in the formation, and some granitic rocks. Where practicable the areas of silicified limestone, greenstone, and granitic rocks have been mapped as separate units.

The chert and the silicified limestone are the two most important units in this group, the former on account of its preponderance as a formational and rock type, the latter on account of its peculiar character and its possible value as a horizon marker. The chert is a microcrystalline rock composed of chalcedonic quartz, which under the microscope shows usually only an aggregate polarization. Much of it is brecciated and recemented with silica. It is believed to be of primary origin—that is, to be a rock formed from original siliceous material. Whether the chert is derived from mechanically or chemically precipitated silica has not been determined. These cherty rocks, however, in common with many of the earlier Paleozoic cherts in the Yukon-Tanana region, show no evidence of secondary origin, either in their internal structure or in their distribution with reference to areas of intensive mineralization. Moreover, the silicified limestone associated with the chert is quite different in character, shows no gradational petrologic features, and occupies areal units clearly distinct from those of the chert.

The silicified limestones are separately mapped. They are pure-white to light-gray or cream-colored rocks, which in most places are greatly silicified. The silicification, however, has not changed their color, which is an important criterion in distinguishing them from the darker-colored chert. Moreover, the silicification has not invariably resulted in the formation of chalcedonic quartz. At several localities, notably on the ridge southeast of Martin Creek, the silicification has produced moderately coarse grained siliceous rocks, which, if gradational phases were lacking, would be difficult to distinguish from pure-white quartzite. It seems most probable that the silicification of these limestones within the chert formation has been due to the circulation of ground water charged with silica derived from the chert.

The chert has been studied in more detail in the valley of Livengood Creek than elsewhere in the district, and this may be considered as its type locality. Mining operations in Livengood Creek and its tributaries have exposed the bedrock at many places and have been very helpful in the accumulation of data regarding the lithologic character of the rocks. Such observations, however, on account of the deep weathering in the chert bedrock below the auriferous gravels, are of little assistance in determining details of structure.

Observations on the rock from the bottom of 25 or more shafts on the bench on the north side of Livengood Creek show that the bedrock is in large part a dark-gray to black chert, in places much brecciated, with a comparatively small proportion of other rock types. The bedrock under the gravels weathers deeply to a red to black clay, which includes numerous particles of unaltered angular chert fragments. The rocks associated with the chert include argillite, shale, greenstone, silicified limestone, and granitic rock. Argillaceous rock in association with the chert was observed only on four claims, of which the Marietta bench shows such rock in largest amount. There it appears as a very carbonaceous shale or argillite, cut by numerous quartz stringers. Five claims showed intrusive bodies of greenstone in the chert. Silicified limestone interbedded with the chert was observed on eight claims, in greatest amount on the Gan and Ready Bullion second-tier benches, north of Livengood, and on an adjoining claim on Myrtle Creek. The silicified limestone is a white to cream-colored rock that weathers to tones of yellow and brown in the bedrock underlying the gravels. Where silicification has not been complete, circulating ground water has not uncommonly dissolved much of the calcium carbonate, leaving a rock that resembles a siliceous sinter. This phase of weathering, however, was observed only in the bedrock underlying stream gravels. Granitic rock is present in Amy Creek and was observed among the fragments of bedrock taken from a prospect shaft at the extreme head of Livengood Creek.

The ridge north of Livengood Creek, including Livengood Dome, is composed largely of dark-gray chert, but no structural data on it are available. About three-fourths of a mile N. 15° E. from Livengood Dome, in the head of Willow Creek, the chert is well exposed. The beds are much faulted and shattered, but one observation that seemed to typify the general attitude gave a strike of N. 75° E. and a dip of 65° S. The chert on Livengood Dome is dark gray to black, much brecciated, and locally banded.

A body of silicified limestone of considerable size occurs on this ridge between Livengood and Myrtle creeks, extending down the spur between Franklin and Wonder gulches into the valley of Livengood Creek. A small body of such limestone is also present in the saddle at the head of Myrtle Creek.

On the south wall of the valley of Livengood Creek the chert is essentially the same in character. Bodies of silicified limestone are present in the East Fork of Gertrude Creek, along the west side of Amy Creek near its mouth, and along the north side of Goodluck Creek just above its confluence with Livengood Creek. The limestone in Amy Creek is well bedded, the beds averaging perhaps 1 foot in thickness. It is little silicified. One observation shows a strike of S. 10° W. with a vertical dip. A body of graphitic argillite, similar to that observed on the Marietta claim, intervenes between this limestone and the chert in Livengood Creek.

Reports from many prospect shafts on the South Fork of Hess River, supplemented by examination of the dumps at numerous places, show that the bedrock underlying the gravels is mainly dark-gray or black chert with some argillaceous rocks. One body of silicified limestone is known to be present along the west wall of the valley about a quarter of a mile above the road house opposite the mouth of Alabam Creek.

The rock along the ridge east of the South Fork of Hess River is universally chert, but good exposures showing structure are lacking. The chert on the point of the spur northwest of Alabam Creek is worthy of especial note on account of its extremely brecciated and recemented character. A little red slate was noted in talus at the heads of Patterson and Slope creeks. A large body of silicified limestone, resembling pure-white quartzite, occurs along the ridge southeast of Martin Creek.

The ridge around the head of Moose Creek is almost entirely chert. One structural observation shows the chert to strike N. 65° E. and dip 80° SE. Small amounts of cherty grit and chert conglomerate are also present on this ridge.

On the slope of the spur on the east side of Butte Creek a good deal of shale and slate and a little sandstone were found in association with the chert. This spur is mapped as a part of the chert formation. The bedrock of Crater Creek is mainly chert. The shaly and sandy beds above mentioned may be part of another formation infolded or infaulted, or they may indicate a change in the character of the sediments to the east. The former hypothesis seems the more probable.

That the chert series continues to the northeast is indicated by the following facts: The ridge forming the divide between Tolovana River and Victoria Creek is shown by the traverses of Prindle and Hess (1904) and Stone (1906) to consist of chert, white quartzite, and shaly beds. It is not improbable that the white quartzite recorded represents the silicified limestone recognized farther west. Stone's traverse also shows many outcrops of quartzite in the valley of Victoria Creek, together with some chert, which may possibly indicate the continuation of the chert series that far northeast, in a more metamorphosed phase.

Southwest of the Tolovana district the chert continues along the ridge north of the West Fork of Tolovana River, as shown by the traverse of Prindle and Johnson (1909). Chert as a formational unit, however, seems to end at about meridian 149° 20′, at the head of Mud Fork of Troublesome Creek, apparently not continuing southwestward into the Rampart district.

Little is known of the cherty rocks adjoining the Carboniferous rocks on the northwest, partly because this occurrence of chert has been studied only near the Carboniferous series and partly because of lack of exposures along the ridge northwest of the North Fork of Hess River. The line drawn between the chert and the Carboniferous rocks is based only on differences in lithologic character and is not considered final.

One observation taken on the chert northwest of the Carboniferous rocks shows a strike of N. 40° E. and a dip of 35° SE. The presence of numerous dikes and some fairly large bodies of basaltic igneous rock, including diabase and basalt, in this chert area indicates that the large area of basic intrusives known farther west and southwest lies in close proximity to these rocks.

IGNEOUS ROCKS.

Intrusive rocks, similar in part to those which occur in the Middle Devonian sequence, are likewise represented, though to a much less degree, in the chert. There are many basaltic intrusives in the chert in Livengood Creek and at other localities to the northeast. Many such dikes, particularly in the valleys where circulating waters have been most active, have developed a decided greenstone habit, but similar rocks on the ridges are not invariably altered to the same extent. Basic intrusives are abundant and large in the chert northwest of the Carboniferous sequence.

The chief known occurrence of granitic rock is in Amy Creek, where a body of albite granite intrudes the chert formation. On the ridge east of Butte Creek a syenite porphyry intrudes the country rock.

STRUCTURAL RELATIONS.

The few structural observations so far obtained on the chert serve to show the structure only in a most general way. There appears to be a general strike of about N. 65° E. with fairly steep dips to the southeast. Enough observations have not yet been obtained to prove this general dip to the southeast, but the evidence in hand suggests it strongly. If this is the true dip the main body of chert can not be thought of as a simple synclinal or anticlinal occurrence.

This southeastward dip causes the chert formation to pitch under the Middle Devonian beds, thus at first sight suggesting that the chert stratigraphically underlies the Middle Devonian rocks. This interpretation, however, is deemed untenable, because if such were the case the chert would have been recognized in the stratigraphic sequence exposed in the White Mountains and vicinity. The idea is advanced therefore that the chert probably represents part of a sequence of Paleozoic rocks, overturned to the northwest. In the light of this interpretation the chert is believed to lie stratigraphically above the Middle Devonian rocks. It will require a much more detailed study to determine whether the chert lies conformably or unconformably on the Middle Devonian.

The width of outcrop of the main chert belt in the South Fork of Hess River (between 8 and 9 miles), together with the isoclinal dips, suggests strongly that there is much duplication of beds. It is likely that close overturned folding is the major structural feature, but whether the folds are dominantly anticlinal or synclinal is not known. Extreme brecciation at certain localities suggests faulting within the chert. The recognition of these facts without the details necessary to determine the magnitude of the duplication renders any estimate of thickness very unreliable. In general, however, the absence of any considerable area of infolded beds over a belt 8 miles or more wide, in rocks having such a structure, argues for a very considerable thickness of the beds, amounting probably to several thousand feet.

AGE AND CORRELATION.

Although the chert is interpreted to lie stratigraphically above the Middle Devonian beds, the relation between the two is obscure. However, the age of the chert formation is known within certain limits—that is, it is believed to be not older than Middle Devonian nor younger than Pennsylvanian. The latter inference is based on the presence of Pennsylvanian fossils in the Carboniferous rocks northwest of the main chert belt. These Pennsylvanian beds are believed to overlie the chert and older rocks of the district unconformably.

The chert is a new unit in the stratigraphy of the Fairbanks quadrangle, and hence no formational correlation is possible. It is worthy of note, however, that Blackwelder,[1] in his traverse down Beaver Creek, noted in its lower course a series of rocks the most abundant of which were "basic lavas, tuffs, and breccias, associated with massive chert, cherty dolomite, siliceous slate, and black slate, and graywacke flags." He recognizes the lack of similarity of such a sequence to anything observed by him in the White Mountain section and does not attempt to assign it to a definite stratigraphic horizon. It is possible that the chert formation may be represented in part by these rocks.

CARBONIFEROUS ROCKS.

AREAL DISTRIBUTION.

A belt of rocks of Carboniferous age extends from the northeast corner of the Tolovana district in a general southwesterly direction into the valley of Hess River. This belt is about 2 miles wide and has a known extent of about 15 miles. Its lateral limits, however, are defined only on lithologic grounds.

LITHOLOGIC CHARACTER.

This Carboniferous series was first recognized by Prindle[2] and described as "greenish, grayish, and black slates, with siliceous material." Rocks of similar appearance were observed by the writer at the head of Wilson Creek, near the line of the Prindle and Hess traverse of 1904, and along a narrow zone northwest of the North Fork of Hess River. The rocks in that vicinity are sandstone, slate, shale, and argillite, with a minor amount of chert. Basic intrusives are also abundant.

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[1] Blackwelder, Eliot, Geology of the northern part of the Yukon-Tanana region: U. S. Geol. Survey Bull. — (in preparation).

[2] Prindle, L. M., The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 337, pp. 22-23, 1908.

STRUCTURAL RELATIONS.

No structural data were collected on the low ridges in this part of the district, and the only hope of procuring further data of this sort is by hunting outcrops in the timber and tundra-covered valleys. Prindle[1] reports that these rocks dip southeastward under the older formations. This structure is in accord with the regional structure as observed in the chert belt and in the older rocks.

This belt of Carboniferous rocks, as mapped, trends about N. 50° E., which is from 10° to 15° at variance with the regional strike of the older rocks. It is possible that this variation may denote an unconformable relation to the underlying rocks. The Carboniferous rocks are believed to end in the South Fork of Hess River, along the fault zone previously postulated.

AGE.

Three fossil collections have been made by Prindle[1] and Hess, and it is upon these that the age determination is based. Lists of these fossils have been twice published and need not be included in this paper. It suffices to say that Mr. Girty regards the fauna as representative of the Pennsylvanian or possibly of the Permian.

IGNEOUS ROCKS.

The igneous rocks of the Tolovana district are divisible broadly into two general types, the extrusive and the intrusive rocks, which, however, are not altogether mutually exclusive. Much detailed petrographic and stratigraphic study in the Yukon-Tanana region will be necessary before any comprehensive discussion of the igneous rocks will be possible.

The distribution of certain basic extrusive lavas of Devonian age is discussed on page 237. Little is known of their original petrographic character. In the vicinity of Livengood they are serpentine rocks, cut by other serpentinous veinlets and stringers. Considerable magnetite is also present. This serpentine is greatly crushed and altered, a fact which is most apparent at Livengood, where such rock is well exposed. It is quite patent that the serpentine is a secondary product, derived from the alteration of some basic rock of unknown original character. This serpentine resembles petrographically the long ridges of serpentine mapped by Prindle[2] and the writer in the Circle quadrangle, to the east of the Fairbanks quadrangle. It is a well-known fact that basic volcanism has been a recurrent event in the Paleozoic and Mesozoic history of the Yukon-Tanana region and in the Tertiary history of southwestern Alaska. Hence general petrographic similarity can not be accepted as the sole basis for correlation of these rocks over large areas, but subsequent work may demonstrate the presence of distinctive petrographic features which will justify such correlation.

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[1] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, p. 46, 1913.

[2] Prindle, L. M., A geologic reconnaissance of the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, pl. 2, 1913.

Certain other basic igneous rocks, described generically as greenstone by earlier workers, occur in the Tolovana district and in the areas to the east and west. Some of these are doubtless extrusive lavas in the Devonian sequence, and others may be intrusive rocks of various ages. The greenstone sequence along the Yukon from Fort Hamlin to the mouth of Hess River is thought by Prindle to belong to the extrusive type. Likewise the greenstones in the Devonian rocks northeast and southwest of the Tolovana district are probably in large part flows contemporary with the including sediments. On the other hand, certain bodies of basic igneous rock in the Tolovana district, and doubtless others in near-by areas, which are younger, are probably post-Paleozoic. Within the Tolovana district proper these rocks seem to be mainly intrusive, but it is likely that in unexplored areas they have extrusive phases. It is difficult and at present quite impracticable to separate the basic rocks on the basis of age for two reasons—first, because Mesozoic rocks in large mappable units have not been recognized in this district, and second, because the degree of alteration of the basic intrusives is not dependent alone on their relative age and is therefore an unsafe criterion for drawing age distinctions over large areas. Hence all the basic intrusives and extrusives, with the exception of the serpentine, are mapped as a unit.

It is worth while, however, to describe briefly the basic rock at certain localities in the Tolovana district where it appears to be intrusive. The body of basaltic rock lying along the north side of Amy Dome ranges in character from a basalt to a pyroxene andesite. At the east end of the area mapped the rock is typically basaltic, being composed essentially of labradorite, pyroxene, and magnetite. Much yellowish-green and colorless chloritic material is present in veins and seams and in the body of the rock, indicating considerable alteration. At the west end the rock appears to be a porphyritic pyroxene andesite, composed essentially of augite and oligoclase-albite, with magnetite. It shows little or no alteration. Though these two rocks are mapped as a single unit, more detailed work may serve to differentiate them as separate types, perhaps of quite different age. The sodic character of the feldspar seems to indicate that the pyroxene andesite is to be correlated with other sodic rocks on this ridge, which are almost certainly of Mesozoic or Tertiary age.

Thin sections of two dikes found in the chert bedrock in Livengood Creek show a basalt and a diabase. The basalt is much shattered and seamed by veinlets of calcite and chloritic material and has a general greenstone habit, the feldspars being chloritized and indeterminate and the mafic minerals, with the exception of magnetite, being entirely chloritized. The diabase is less altered, the feldspar showing only partial chloritization, and the pyroxene, a titaniferous augite, being comparatively unaltered.

A basic rock that cuts the silicified limestone on the spur between Franklin and Wonder gulches, in the Livengood Valley, showed considerable alteration but is nevertheless clearly determinable as an olivine basalt.

Another dike rock of diabasic affinity cuts the Carboniferous rocks on the spur east of Half Moon Creek. This rock contains labradorite, augite, chloritized biotite, quartz in the interstices, and magnetite. It is a quartz diabase, as nearly as it may be described.

Only one thin section of the basic intrusives northwest of the North Fork of Hess River was studied. This section, however, seemed to be typical of these rocks. It is a granular rock, composed of augite and labradorite, both partly altered; biotite, a little chloritized; quartz; and magnetite. It should also be described as a quartz diabase. Similar rocks on the ridge north of the forks of Hess River seem to be coarser in grain, approaching more nearly a gabbroic type. Neither of these types could be considered as showing a greenstone habit.

All the basic rocks, including both intrusives and extrusives, irrespective of age, are mapped collectively as a unit.

Intrusives of acidic and intermediate types are also present in the Tolovana district and surrounding areas. It is believed that these are in part of Mesozoic age and possibly in part of Tertiary age. It is likely, however, that they represent several epochs and numerous stages of intrusive volcanism.

Dioritic rock crops out in one place on the spur between Lillian and Olive creeks, forms the top of Amy Dome, and is present in the valley of the North Fork of Hess River. There are some differences in these occurrences, though a general family resemblance is observable. The rock between Lillian and Olive creeks is a hornblende diorite, somewhat altered. It consists of cloudy plagioclase of the composition of basic oligoclase or acidic andesine, hornblende, a little pyroxene largely altered to secondary hornblende, epidote, sericite, and calcite, the last two derived largely from the feldspar. Several specimens from Amy Dome show the presence of hornblende diorite and quartz-hornblende diorite, both much chloritized, kaolinized, and sericitized. Epidote is also developed. The rock in the Hess River valley is likewise an altered hornblende diorite.

Of particular interest are an albite granite exposed on Amy Creek and a soda rhyolite which intrudes the Middle Devonian sediments on the top of the ridge at the heads of Ruth, Lillian, and Olive creeks. The rhyolite is a porphyritic acidic rock found in association with a lode deposit, described on page 274. The phenocrysts are albite ($Ab_{91}An_{9}$), and the groundmass is composed of similar albite, quartz, and prismatic and irregular areas of iron hydroxides, suggesting the presence of original hornblende or biotite. This rock is heavily mineralized by pyrite and is cut by veinlets of quartz.

The dioritic and more acidic intrusives, including the two types above described, are mapped as a single unit.

QUATERNARY DEPOSITS.

TYPES.

Three general types of Quaternary deposits have been recognized in the Tolovana district—fluviatile deposits, silts, and residual material.

The fluviatile deposits are those which have formed and are still in process of formation in stream valleys, under the influence of running water. They are divisible into two subtypes, the older and the younger deposits, which are represented, respectively, by the bench deposits and the present stream deposits. The bench deposits occupy the bottoms of old erosional channels. Along the present streams that occupy the same channels as their predecessors and have cut through the older deposits it is in places possible to observe details of their character and structure, but on account of extensive changes in drainage, the overlying mantle of later sediments and residual material, and the covering of vegetation in the valleys, the places where observations can be made on the bench deposits are very few. Over much of the Tolovana district the valleys are open, many of the interstream divides are low, later sedimentation is widespread, and changes in the stream channels have been common. Hence, knowledge of the bench deposits is dependent in large measure on excavations resulting from placer-mining operations. At present the only bench deposits that are open to examination are those in the old stream channel along the north side of the valley of Livengood Creek.

The silts are the fine sediments which mantle many of the fluviatile deposits and extend upward onto the spurs and the low interstream divides.

The residual material comprises talus, material accumulated through solifluction, and rock débris nearly in place.

BENCH DEPOSITS.

The bench deposits on Livengood Creek occur in a single well-defined channel, which begins at some undetermined point in the upper part of the Livengood Valley and extends down the valley to its junction with the valley of Myrtle Creek. At this point there is a decided steepening of the grade of the old channel, and it has been established by drill holes and prospect shafts that the gravels continue downward on this grade to join with similar gravels which are deeply covered in the lower part of Livengood Valley.

Underground mining on these bench gravels has not been carried far enough to make any generalization concerning their width or concerning the position of the tributary channels that must have joined the main channel from both sides of the valley. Yet the general alignment of the mining plants along the auriferous channel on this bench and the offset of certain plants toward the creek indicate the presence of such subsidiary channels.

The older fluviatile or bench deposits of Livengood Creek consist essentially of well-rounded gravels, commonly ranging from half an inch to a foot in diameter. They are composed largely of dark-gray and black chert, with a smaller proportion of basic igneous rocks and some silicified limestone. The average thickness of the gravels in the main channel, calculated from 13 observations in the underground placer workings, is about 15 feet, but the thickness is by no means constant, the minimum and maximum measurements being, respectively, 6 and 40 feet. At every locality except one the gravels formed a solid sheet, without any important interstratification of finer material. On the Ready Bullion, a second tier bench opposite the lower part of Discovery claim, the section in the shaft shows 9 feet of gravel on bedrock, overlain by 4 feet of muck, which in turn is overlain by 16 feet of gravel.

On the spur between Franklin and Wonder creeks, about 1,000 feet north of the auriferous bench channel, the depth of bedrock is only 4 feet. A series of drill holes extending up this spur at intervals of 100 feet for a distance of 600 feet have disclosed the presence of a still higher body of gravel, lying in a channel-like depression that attains a depth of 106 feet. The northern limit of this gravel up the spur has not been determined. The exact significance of this high gravel deposit is not known. If drilling shows such gravel to be present on the other spurs along the north side of Livengood Creek, in a bedrock channel, it will be taken as evidence of the existence of an old channel of Livengood Creek formed still earlier than the auriferous bench channel. If present only on a single spur, this body of gravel may be interpreted as a delta deposit, under assumed conditions of lacustrine or estuarine inundation. The gravelly material in this deposit is composed largely of white flint and quartz, differing noticeably from the auriferous bench and stream gravels of Livengood Creek, which are composed mainly of dark flinty material. This white gravel resembles most closely the lighter-colored chert that forms Livengood Dome, to the north.

PRESENT STREAM DEPOSITS.

The present stream deposits occupy the erosional channels of the existing streams and have been laid down under the action of running water during the latest cycle of erosion, subsequent to the period of general silt alluviation. It is believed that these deposits, beginning at the headwaters, extend downstream as alluvial blankets, overlying the heavy deposits of silt that fill the valley bottoms. The deposits differ in character at different localities, owing in large part to the adjustment of the recent streams to a new base-level. This adjustment has worked progressively upstream, resulting in the simultaneous deposition of coarse and fine sediments at different localities. Local conditions, such as superimposed drainage and stream piracy, have also operated to cause abnormal conditions of erosion, resulting in differences in the character and distribution of the deposits.

The recent deposits are composed at some localities of gravels alone, but more commonly they consist of gravels overlain by finer sediments, largely muck, or silt containing a large quantity of plant remains. It is only where the overlying silt is absent or where mining operations have exposed the gravels in the creeks that the gravels may be seen. Thus the larger streams, such as Tolovana and Hess rivers, have well-developed gravel bars in their upper courses. Likewise some of their larger tributaries, in their lower courses, flow over gravel beds. But the headwater tributaries flow usually between cut banks of silt and carry only a thin veneer of iron-stained gravel in their beds, the main body of gravels being buried beneath the silt.

The main gravel sheets of the present streams are not materially different in character from the bench gravels, being of moderate size, well rounded, and made up of rock débris of the same sort. The overlying muck, in the headwater tributaries, is thought to be reworked sediment derived largely from the heavy body of silt that mantles the region. It is likely that sediments of intermediate grade lie between the stream gravels and the overlying silt at many localities. This condition is known to exist in Livengood Creek, at the mouth of Gertrude Creek. A shaft at this locality exposed 10 feet of gravel lying on bedrock and overlain by fine gravel and sand (the "chicken feed" of the miners), which in turn is overlain by 6 feet of muck. The iron-stained gravels that occur as a thin veneer in the beds of some of the headwater streams are only imperfectly rounded and show the effects of rapid transportation at stages of high water. Such gravels are relatively insignificant.

SILTS.

The silts form a general covering over the older fluviatile deposits, filling the valleys and mantling the lower spurs and interstream divides. They have been observed up to an elevation of 1,200 feet in the saddle between Livengood Creek and the South Fork of Hess River. Later excavations on higher divides may prove the existence of such silts at still higher elevations. It is of interest in this connection to note that Prindle[1] maps terrace deposits up to an elevation of 1,800 feet in the valley of Beaver Creek, up to 1,600 feet on the east, at the head of Tolovana River, and up to 1,400 feet at the head of the West Fork of Tolovana River. It may not be affirmed positively, however, that the silt was deposited uniformly up to an elevation of 1,200 feet or higher. It is quite possible that the alluvial surface, at the end of the period of silt sedimentation, was a sloping one, attaining an elevation of 1,200 feet or higher on the interstream divides but descending gradually to some unknown lower level in the lower valleys.

On Livengood Creek the original silt is a very fine sediment, ranging in color from black to blue-black, with local brown or yellow-brown phases. Specimens of the black silt after drying become an ordinary earthy yellow-brown color. The silt is bedded, but on the Livengood bench, where it was seen most often, it is frozen and seamed with ice, and its examination in the mining shaft gives most unsatisfactory results. Detailed microscopic studies of the silts have not been made, but they appear to be composed mainly of quartz grains, with considerable amounts of mafic minerals, including mica and some clay.

RESIDUAL MATERIAL.

The Tolovana district has a heavy covering of residual débris produced by weathering, ranging in size from clayey material to coarse rock talus. The talus, however, is restricted to the sides of high knobs that stand above the general ridge level. The tops and sides of the low ridges and the sides of the high ones are for the most part covered by a mantle of residual material, derived from the underlying bedrock. This material is produced by the action of frost and water and is not rounded or sorted. Such material on the sides of the ridges moves gradually downhill, producing, in localities where the conditions are favorable, solifluctional slopes. Much of the muck covering the present stream gravels doubtless migrated from the hills downward into the valleys in this manner.

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[1] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pl. 8, 1913.

QUATERNARY HISTORY.

As no Tertiary deposits are known to be present in the Tolovana district, the conditions existing at the beginning of the Quaternary period can not be fully understood. The oldest unconsolidated deposits of which there is any record are the older fluviatile gravels, such as those on the bench along the north side of Livengood Creek. At the time of their deposition the hills and valleys showed a mature topography having the general configuration of the topography of to-day. The master streams, however, had a much lower base-level than at present, and the streams were more deeply incised in their valleys. Normal stream gradients with the characteristic headward steepening were the rule, and aggradation of gravelly material had worked progressively upstream into the headwaters. In their lower courses the streams were in the stage of late maturity, had widened their valleys somewhat by lateral planation, and were aggrading with fine sediments.

At this stage in the physiographic history the base-level of the master streams began to be elevated, and aggradation of the valleys by silts became the universal condition. As a result, all the valleys were deeply buried with silt, which at many localities was deposited up to an elevation of 1,200 feet. The initiation of this new base-level, however, was in general a gradual process, but certain observations in the Tolovana drainage basin show that there was at least one long intermission in the process during which the base-level remained constant.

On Ready Bullion, a second tier bench opposite the lower part of Discovery claim on Livengood Creek, the deepest shaft shows a depth to bedrock of about 100 feet. On claim No. 3 below Discovery on Myrtle Creek, near the mouth of that stream, the depth is 240 feet to bedrock. The Ready Bullion adjoins on the downstream side claim No. 1 below Discovery on Myrtle Creek. Hence within three claim lengths there is a difference in depth in the shafts of 140 feet, and this, in addition to the surface slope from the Livengood bench to the Myrtle Creek claim No. 3 below Discovery, would produce a gradient of about 200 feet in that distance, or about 265 feet to the mile. This steep gradient in the lower part of the old Livengood channel is due mainly to the fact that this locality was very close to the head of Livengood Creek, as it existed at that time. The preservation of this steepened grade was due apparently to such a pause in the sedimentation, whereby the deposition of silt was temporarily discontinued at an elevation of about 625 feet. It was during this period of stability of the regional base-level that the valley of Livengood Creek by headward erosion was extended northeastward, eventually tapping the headwater drainage of the South Fork of Hess

River. It was also during this pause that the auriferous bench gravels of the Livengood Valley were deposited.

Additional evidence of this period of stability during the silt alluviation is shown on Olive Creek, a tributary of Tolovana River heading against Ruth Creek. On Discovery claim, about a mile from the head of the creek, the bedrock is covered by 10 feet of gravel; yet two claim lengths downstream the depth to bedrock is 94 feet, and the auriferous gravels, 14 feet thick, continue out into the valley of Tolovana on a normal grade, being separated from the underlying silt by a seam of clay. This locality likewise has an elevation of approximately 600 feet and evidently affords another example of a steep headwater grade preserved by the silt alluviation.

A feature of the same sort is reported at a similar elevation on Ester Creek, about a mile to the east.

Features almost identical with this have been found at numerous other localities in interior Alaska, where silt sedimentation has been prominent. Thus on Long Creek, in the Ruby district, near the mouth of Snow Gulch, an abrupt steepening of the bedrock grade has been observed by Harrington.[1] Eakin[2] reports a similar steepening on lower Midnight Creek, also in the Ruby district. In this locality, as on Olive Creek, the richest auriferous gravels lie some distance above bedrock. Likewise in the Hot Springs district, according to Eakin,[3] on American Creek bedrock lies at a depth of 18 feet for a distance of a mile and then within half a mile drops to a depth of 165 feet. Still other examples of this physiographic anomaly could be mentioned, such as the abrupt increase in the depth of the gravels reported to occur on Chatanika River and Cleary Creek, in the Fairbanks district. It seems very significant that all these features are at or near the 600-foot elevation.

After this period of stability progressive elevation of the base-level was again renewed and resulted in the further burying of the old erosion channels up to an elevation of 1,200 feet or higher. It is likely that another period of stability of the regional base-level may have succeeded the termination of the silt sedimentation, but its effects are not so evident. The high rock-cut benches on the spur west of Ruth Creek, previously described, may be correlated with such a second period of stability. Further evidence on this point is lacking, perhaps owing to any one or all of three reasons—first, because the base-leveling may not have developed to any marked degree, on account of the reduction of erosion to a minimum through the extreme elevation of the base-level; second, because such high-level features have been exposed to erosive agencies for a longer period of time than the lower ones, subsequent to the removal of the silt; and third, because mining and prospecting have not been carried on in this district at the 1,200-foot elevation, and hence old stream gradients, if still preserved, remain concealed.

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[1] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. — (in preparation).

[2] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, pp. 41-42, 1914.

[3] Eakin, H. M., oral communication, 1917.

The ultimate cause of the changes in base-level that brought about the silt alluviation is not yet definitely known; nor are the physical and climatic conditions under which the silt was deposited entirely free from question. Eakin [1] has explained the silt as a fresh-water lacustrine deposit, laid down in one of a series of great interior lakes, which were caused by glacial damming of the trunk drainage channels of interior Alaska during the glacial epoch. Brooks, in his preface to Eakin's report, suggests the possibility of crustal warping as a causal agency. Harrington [2] shows the probable existence of marine terraces in the lower Yukon, at an elevation of 600 feet. If the existence of these marine terraces is eventually proved, there will be good reason for correlating them with the period of stability of base-level at the 600-foot elevation in the valley of Livengood Creek. Under this interpretation the silts of the Tanana and Yukon valleys would have to be regarded as estuarine deposits. It seems best at present to allow this question to remain open; but the assumption that these silts were deposited in quiet water seems to the writer to be almost a necessary beginning to any interpretation.

The origin of the high-level lakes in the silt is not entirely understood. They may occupy in part original depressions in the alluvial silt plain, but, on the other hand, subaerial erosion may have been a potent factor in the modeling of such depressions.

It is almost necessary to assume that sediments as fine as these, if they were exposed to the action of the winds subsequent to their deposition, were redistributed to a marked degree. It should be possible by microscopic examination to determine the size and character of the grains and the degree of sorting, and in this way to learn something of the climatic conditions subsequent to their deposition and of the amount of subaerial redistribution which they have suffered. It is hoped that subsequent detailed studies of this kind may yield valuable information as to the genesis of these deposits.

After the deposition of the silt the base-level of the region was again lowered, and active erosion immediately began. One of the most striking effects of the new cycle of erosion, acting on the silt deposits, was the frequent occurrence of stream superposition. Thus Livengood Creek began to cut a channel in the silt along the south side of its valley and, after eroding through the silt, was superposed upon hard bedrock, in which it was obliged to cut a new channel. Stream piracy likewise became common, many streams cutting back across silt-covered divides and claiming drainage systems other than their own. In this manner the South Fork of Hess River, cutting back through an antecedent divide in its valley about east-northeast of Livengood Dome, regained a part of its upper drainage which had previously been stolen by Livengood Creek. Such readjustments have produced most of the present drainage anomalies.

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[1] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, pp. 73–74, 1916.

[2] Harrington, G. L., The Anvik-Andreafski region, Alaska: U. S. Geol. Survey Bull. 683 (in preparation).

The immediate result of the rejuvenation of the streams was the removal of a large part of the silt deposits, particularly in the headwater tributaries. It is not known exactly to what extent the removal of the silts was carried, but it is certain that they were not completely removed in the lower parts of the master streams, because the regional base-level has never been lowered to the position it held prior to the deposition of the silts. It was lowered to a certain intermediate position and remained approximately there, and the streams have readjusted themselves to a normal stream gradient. In so doing the recent stream gravels were laid down upon stream bottoms of silt. These constitute what Eakin [1] has designated "inlaid gravels." This base-level, which still continues, must have been in existence a very long time, for the present streams have lowered their grades until they have become generally sluggish, except in the extreme headwaters. Not only was a body of stream gravel deposited progressively upstream, but the present condition of the streams indicates that the deposition of this gravel was followed by extensive silt aggradation in their lower courses, the silt being derived from the older silts. The natural silt levees along the lower course of the Tolovana, the swamps and lakes extending toward the hills from the levees, the meandering course of the river, and the network of logs in the river bottom prove that the silt beds in which it is now flowing were deposited by river action and indicate extensive silt aggradation in the lower river courses, superimposed on the river gravels.

Tolovana River below Trappers Cabin, where the river leaves the gravel bars, has a well-developed system of intrenched meanders in the fluviatile silts. These meanders extend downstream to a point about 30 miles below the log jam, where the high silt banks become lower and the current very much less. This is an anomalous feature, difficult to explain. It is possible that the present and earlier log jams in the channel have had sufficient effect to produce this result. Of special significance, as bearing on this interpretation, are the interlacing water-logged trees that cover the bottom of the river below the log jam.

The fluviatile silt deposits in the headwater streams are due to headwater aggradation. The present streams have reduced their grades to a point where they can no longer transport gravels, even in their headwaters; and the headwater silt deposits represent detrital material which has accumulated at the bases of the steep headwater grades.

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[1] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, p. 61, 1916.

MINERAL RESOURCES.

GENERAL FEATURES.

At Livengood, as in every new mining camp, attention has first been directed to the mineral deposits most easily and cheaply won—in this camp the gold placers. Only the older and richer auriferous bench gravels have so far been mined. The present stream gravels may later prove worthy of attention.

In 1916 twenty-one plants were engaged in mining the bench gravels of Livengood Creek and one in mining the creek gravels. These operations were carried on by underground mining. On Gertrude, Ruth, Lillian, and Olive creeks five small plants were engaged in open-cut mining, and four other plants were planning to begin operation late in the season or early in 1917. In all 27 plants were operated, compared with 10 operated in 1915. The value of the gold produced in 1916 is estimated at $700,000, compared with a production of $80,000 in 1915.

Development work has been attempted on one gold lode prospect, but little has yet been accomplished. A number of minerals other than gold have been found in the concentrates, showing at least the presence of such minerals in the neighboring hills. It may be that bodies of these minerals worthy of exploitation will ultimately be located and mined.

ECONOMIC CONDITIONS.

MEANS OF COMMUNICATION.

Livengood, the principal settlement in the Tolovana district, is reached by two general routes—overland by trail from Olnes, on the Tanana Valley Railroad, or by water by way of Tolovana River. The trail from Olnes is used both in summer and in winter, and the winter mail reaches Livengood by this route. In summer only the first-class mail comes overland, most of the second-class matter coming up the Tolovana. As a route for the transportation of supplies, however, the trail is little used in summer, owing to its poor condition; and even as a winter trail it is open to serious objections because it crosses several drainage systems and the intervening hills, including Wickersham Dome, and is therefore very hilly and exposed for considerable distances to the wind and drifting snow.

The river route is the more practicable for freighting. At ordinary stages of water supplies may be taken by gasoline scows and small steamboats up the Tolovana as far as the log jam. A tram has been built around the jam, and supplies are therefore unloaded, trammed around, and reloaded into small barges and launches, which relay the freight upstream to Trappers Cabin or to West Fork, according to the amount of water in the river. In stages of low water it is often necessary to transport supplies from Trappers Cabin to West Fork by means of poling boats. In the past supplies have been freighted by teams from West Fork to Livengood, but during the summer of 1916 a tramway was in process of construction between these two points. When completed, this should materially cheapen the transportation.

One of the great difficulties of the river route is the low water which often prevails in the Tolovana for considerable periods. For 30 miles below the log jam the river is difficult to navigate in low water, being tortuous and lined along its bottom with water-logged timber and snags. Above the log jam low water causes even greater difficulties. Largely for this reason a winter trail, known as the Happy trail, was built during the winter of 1915–16 up the east side of the Tolovana Flats to West Fork, connecting at its lower end with the Fairbanks-Hot Springs trail. This is an excellent trail and should become a valuable means of access to the Tolovana district. It is expected that the Happy trail will be much used to bring from the log jam to West Fork in winter supplies that were landed at the log jam by boat in summer, and some supplies may be freighted all the way from Fairbanks by this route.

SUPPLIES.

The cost of freighting supplies from Fairbanks to West Fork by way of Tolovana River is 3½ cents a pound, and by team from West Fork to the mines on Livengood Creek about 3½ cents more. The tramway between West Fork and Livengood should reduce the latter rate. The cost of winter freighting from Fairbanks to Livengood, by the trail from Olnes, is 5 cents a pound. The summer rate over the same trail is 15 cents a pound. Supplies were scarce and costly in Livengood during the early part of the summer of 1916, but this condition should not exist again.

TIMBER.

Good-sized timber for mining purposes and general construction is available in the valley bottoms, and a sawmill at West Fork is already at work utilizing it. Trees of a diameter of 2 feet at the base may be had in the bottom land of the Tolovana Valley, and even larger ones at some localities. There is plenty of timber between 1 and 2 feet in diameter. In the upper valley of Livengood Creek, near the mines, the trees are smaller, being for the most part less than a foot in diameter and becoming smaller still up the sides of the valley.

The timber at the mines is needed most for fuel, and for this purpose as well as for timbering in the mines the supply is quite adequate.

The district is naturally well supplied with timber, but gross carelessness on the part of woodchoppers near Livengood resulted during the summer of 1916 in extensive forest fires, which destroyed large amounts of standing and cut timber, badly damaged several mining plants, and seriously threatened many others.

Prior to the fires, wood for fuel cut in 16-foot poles and delivered to the mines cost $7 a cord. On adding the cost of sawing and considering the resulting shrinkage of the cord, it is figured that wood in 4-foot lengths costs about $10 to $12 a cord. The forest fires will ultimately increase the cost of fuel materially.

WATER.

Water for sluicing on Livengood Creek is obtained from ditches that tap the creek and its northern tributaries. During periods of dry weather, however, this source of supply is inadequate, and steps have been taken toward procuring a part of the water from the South Fork of Hess River. A low divide of unconsolidated material separates the head of Livengood Creek from the South Fork of Hess River, and if a deep channel can be ground-sluiced through this divide, a large amount of water from the South Fork will be available. The possibility of sluicing out such a channel depends on the character of the material in the divide. If the divide is largely muck and fine sediment, the plan will be practicable; if much heavy slide rock is encountered, it will be very costly. During the summer of 1916 a ditch was dug, leading water from Hess River onto this divide, and the process of ground-sluicing was begun.

Two or three mining properties on Livengood Creek just above Myrtle Creek are now obtaining water from the valley of Myrtle Creek.

GAME AND FISH.

The herds of caribou that are so plentiful in the interior part of the Yukon-Tanana region do not approach very closely to the low country near Livengood, but some caribou are killed for food. The moose have been plentiful, but many have been killed, and it is likely that the future will soon show a marked decrease in the supply. Fish, chiefly grayling, are plentiful in Tolovana River near West Fork and form an important source of food.

WAGES.

Men are paid $5 a day besides their board, which during the summer of 1916 amounted to about $3 a day. Thus the cost of labor to the operator may be figured at about $8 a day.

GOLD PLACERS.

PRINCIPAL FEATURES.

The Tolovana placers are not so widely distributed as those in the Fairbanks and Ruby districts, where gold in greater or less amount is found in the valley bottoms of many creeks over a considerable area. On the contrary, mining and prospecting to date in the Tolovana district tend to show a decided localization of the rich ground. Thus, gold placers of commercial value have been found only on Livengood Creek and in the streams draining the ridge between Livengood Creek and Tolovana River. So far no gold placers worthy of exploitation have been found in any of the tributaries of Livengood Creek on the north side, nor on Myrtle, Ready Bullion, or Rosebud creeks, though considerable prospecting has been done on these streams. Prospecting has shown the presence of gold in the South Fork of Hess River and in some of its tributaries, but so far no continuous pay streak, such as that on Livengood Creek, has been uncovered.

The placers are of two types, which are quite distinct on Livengood Creek but grade into each other on the smaller streams. It is apparent also on the South Fork of Hess River that both bench and stream gravels are present, but the courses of the old and new channels appear to cross and recross one another, with the result that the two are apparent as separate units only at certain localities.

Both bench and stream placers are being worked at the present time, but the bench placers have proved the richer and will doubtless continue to furnish most of the gold produced.

LIVENGOOD CREEK.

GEOGRAPHY.

Livengood Creek heads against the South Fork of Hess River, flows in a general direction of S. 70° W. for about 6 miles, turns abruptly at the mouth of Myrtle Creek, and flows S. 20° W. for about 4 miles to Tolovana River. In its upper 6 miles the present valley floor is narrow and the creek is small. Below the mouth of Myrtle Creek the valley floor becomes a mile wide, and it broadens continuously toward the Tolovana. The valley of Myrtle Creek at its mouth is wider than that of Livengood Creek, and it seems evident that Myrtle Creek and the lower Livengood constituted originally the master stream of this drainage system, the upper part of Livengood Creek being only a tributary.

The gold placers so far found occur in the upper stretch of 6 miles, in which several tributaries enter the creek on both sides. Those on the south side, all of which contain auriferous gravels, are Goodluck Creek, Amy Creek, Lucille Gulch, Gertrude Creek, Alder Gulch, and Ruth Creek, named in order going downstream. Lillian Creek, another small tributary containing auriferous gravels, enters Livengood Creek in its lower 4-mile stretch, at the west end of the ridge between Livengood Creek and Tolovana River. The town of Livengood is in the lower part of the upper Livengood Valley, at the mouth of Ruth Creek.

The valley of Livengood Creek is asymmetric in cross section, the creek flowing along the south side. The ridge on the north side descends in long, gently sloping spurs to the present valley floor, whereas on the south side similar spurs of gentle slope but not so long terminate abruptly in rather steep bluffs along the creek. The view of Livengood and the valley of Livengood Creek (Pl. XIV) illustrates clearly this asymmetry.

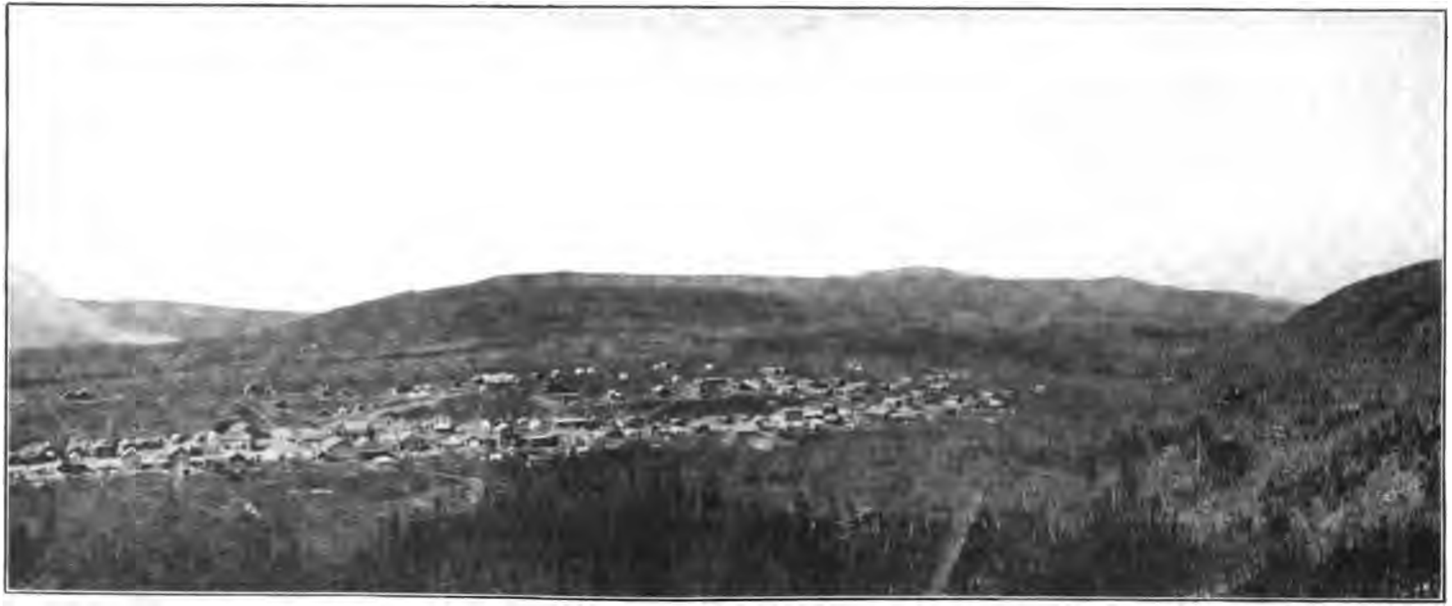
PHYSIOGRAPHIC HISTORY.

The physiographic history of a placer-mining district has an important bearing on the economic geology of its gold placers. This is particularly true of the area drained by Livengood Creek and the adjoining drainage systems. It is believed that an understanding of the principal events in the development of the present drainage may help materially in mining operations and prospecting.

The physiographic history of Livengood Creek and the neighboring drainage channels is complicated. The essential features of the regional physiography are understood in a general way, but only where mining operations have exposed the character and depth of the unconsolidated deposits is it possible to discern the details of drainage changes and associated phenomena.

At the earliest time recorded by the available physiographic data Livengood Creek was a much shorter creek than at present. The bedrock grade of the lower part of the auriferous bench channel is about 265 feet to the mile. With this grade the original stream above the mouth of Livengood Creek must have been very short, the divide being below the mouth of the present Amy Creek. As bearing on this point, the backhand drainage of Wonder, Heine, Goodluck, and Amy creeks, particularly in their headwaters, is of much significance. It seems entirely within reason to believe that these four streams, during this stage of their history, drained northeastward into the South Fork of Hess River.

Then followed the stage of silt alluviation, brought about by an elevation of the regional base-level. When the silt deposits had accumulated to a depth of approximately 600 feet in the Livengood basin, there was a long period of stability, during which the base-level remained unchanged. This silt alluvium preserved the old grade of Livengood Creek up to that elevation and provided for upper Livengood Creek a new temporary base-level. Under this condition of equilibrium Livengood Creek cut back through the rock divide below



LIVENGOOD AND ASYMMETRIC VALLEY OF LIVENGOOD CREEK.

Amy Creek and gradually captured the drainage of the South Fork of Hess River. There are two means of determining just how much of the Hess River drainage was captured. First, a drill hole in the present silt-filled divide at the head of Livengood Creek shows a depth of 205 feet to bedrock. As the elevation of the divide is a little over 1,200 feet, this means that the old channel through this divide has an approximate elevation of 1,000 feet. Theoretically, therefore, it was not possible to capture any of the Hess River drainage below that level, and practically, on account of the headward steepening of every stream gradient, it was not possible to capture all of it above that level. The second piece of evidence is found in the valley of the South Fork of Hess River east-northeast of Livengood Dome, at an elevation of about 1,100 feet, where the creek flows through a narrow gorge. At this point, on claim No. 4 below Discovery, a series of shafts across the valley bottom reveal the fact that in the deepest place bedrock is but 15 feet deep. The overlying deposits are entirely gravel. This, evidently, is the head of the old Livengood drainage system. From this point on the South Fork upstream to the mouth of Alabam Creek the bedrock becomes lower and the unconsolidated deposits become thicker. Just above Alabam Creek, on the second-tier bench claim opposite claim No. 4 below Discovery on Goldstream Creek, the depth to bedrock is 150 feet.

Therefore, subsequent to the silt alluviation in the lower Livengood Valley, up to the 600-foot level, during the ensuing period of regional stability of base-level, Livengood Creek eventually captured all the upper drainage of the South Fork of Hess River and its lower drainage down to the present gorge. It was during this period that the present bench channel in upper Livengood Creek was excavated and auriferous gravels deposited therein.

Subsequently the regional base-level was again progressively elevated, and eventually silts were deposited up to an elevation of 1,200 feet or higher, deeply burying the old Livengood gravels. It was probably at the end of this process of alluviation that the rock-cut benches west of Ruth Creek were evolved.

After the period of silt deposition active erosion was again begun by a lowering of the base-level. Both Livengood Creek and the South Fork of Hess River began to cut channels in the soft silt, and the present silt-filled divide was finally established as the watershed between the two drainage systems. Livengood Creek, however, instead of reexcavating in its old channel was superposed on the south wall of its old valley and after quickly cutting through the silts was obliged to cut a new channel through the solid rock. This superposition explains the rapid steepening of the bedrock grade in Livengood Creek below the town of Livengood. Opposite the wireless station the depth to bedrock is 20 feet, whereas two claim lengths downstream it is 180 feet. The present course of Livengood Creek evidently carries it abruptly off the end of an old spur extending from the south wall of the valley. Lower Livengood Creek eroded in the silts more rapidly than upper Livengood Creek, and the result for a considerable period was the development of rapids just below the present town of Livengood.

The South Fork of Hess River, during the general stream rejuvenation subsequent to the deposition of the silt, established a system which reclaimed a large part of the drainage area it had previously lost, but it has not succeeded in recovering Wonder, Heine, Goodluck, and Amy creeks. After the removal of only 100 or 150 feet of the silts, the South Fork was superposed on bedrock at the present gorge, and this high bedrock barrier has prevented much subsequent erosion in its upper basin. A fact in strict accord with the above interpretation is that of the two rock divides, one just below the present Amy Creek in Livengood Valley and the other at the 1,100-foot elevation in Hess River; the latter and more recent one is the better preserved. The old divide in Livengood Valley has been entirely obliterated, its previous existence being entirely inferential. It is probably owing in large part to the superposition of both Livengood Creek and the South Fork of Hess River on hard rock that the silt-filled divide between the two drainage systems is so perfectly preserved.

The present stream gravels of Livengood Creek were laid down during the period of stream rejuvenation above described. They were formed as a gravel sheet extending progressively upstream. The covering of muck on these gravels is the reworked silt, eroded from the neighboring spurs at a rather late stage in the erosional history, when the headwater tributaries had so reduced their grades that they were no longer able to transport gravels.

BENCH PLACERS.

Pay streak.—The auriferous bench gravels on upper Livengood Creek lie in an old stream channel, which has been traced from a point below the mouth of Wonder Creek downstream to a point below the town of Livengood, a distance of 4 miles. This channel is separated from the present channel of Livengood Creek by a bedrock reef, which crops out at the town of Livengood and is traceable underground upstream almost to the mouth of Amy Creek. Upstream from this point the bedrock barrier between the two channels probably connects with the underground continuation of the spur between Amy Creek and Lucille Gulch. At the lower end of upper Livengood Creek there is another reef, the southwestward and underground continuation of the ridge between Livengood and Myrtle creeks. The old channel passes between these two reefs, apparently hugging close to the north wall of its old valley, as shown by drill holes and prospect shafts on and near the Ready Bullion bench claim. The gravels in this old channel will be found to connect with deeply buried gravels in Myrtle Creek, but as they spread out into what was formerly the larger valley of the two, it is uncertain how well defined a pay streak will be found. It is not unlikely that the gold is too widely scattered in these gravels to be recovered profitably at the present time.

The width of this body of old gravels is not yet known. The width of the pay streak or productive placers, however, may be fairly judged by the lateral extent of the underground workings. The average width of the auriferous channel, as obtained from 15 observations underground, is 127 feet; the maximum is 300 and the minimum 60 feet.

There is a general alignment of the mining plants up and down the bench claims, but certain plants are offset to the south and thus indicate the presence of tributary auriferous channels entering the main channel from that side of the valley. Among these are the auriferous channel on the first-tier bench opposite Discovery claim and on the adjoining Nelson bench; that on the Eagle, a first-tier bench opposite claim No. 3 above Discovery; and possibly also that on the Eldorado bench, about 1½ miles above Livengood.

Placers.—The average depth to bedrock in the auriferous channel, obtained from 20 observations, is 80 feet, and the overburden shows little or no tendency to thicken downstream. The average thickness of the gravels, obtained from the same observations, is 14 feet, and there is a marked thickening of the gravel sheet on the last four or five claims at the lower end of the channel. The overburden is mainly muck or silt, commonly with some slide rock and here and there containing thin seams of fine gravel and sand ("chicken feed"). The gravels commonly range from half an inch to a foot in diameter. The bedrock is at most places a deeply weathered, locally much brecciated dark-gray to black flint or chert. It is in some places strongly mineralized with pyrites. The bedrock at a few localities is greenstone and at a few others silicified limestone. Only on the Marietta claim, where the bedrock is a carbonaceous shale or argillite was any argillaceous bedrock observed.

At most localities all the gravel carries more or less gold, but only the lower part carries enough gold to warrant its removal under present conditions. The upper part of the decayed bedrock likewise contains gold. Observations from 15 working shafts show that about 3 feet of gravel is being regarded as workable, on the average, and about 1½ feet of decayed bedrock. It is in places necessary, however, to remove more than 5 feet of material in order to give working room. The highest gold content is in the lowest part of the gravel and on the surface of the bedrock. Where the bedrock is limestone the gold penetrates but a few inches into the rock.

Information given by the mining operators leads to the belief that the average tenor of the productive ground is at least $1 a square foot of bedrock. Above Amy Creek, however, the gold content of the gravels is lower. On the assumption that an average thickness of 5 feet of gravel and decayed bedrock is removed, the returns would be $5.40 to the cubic yard of material mined and sluiced. If dredging or hydraulicking methods are ever used the entire overburden must also be included in the yardage. On the assumption that 1½ feet of bedrock and 80 feet of overlying gravel and overburden are removed the average-tenor would be 33 cents to the cubic yard.

The gold.—Considerable differences exist in the color, shape, size, and porosity of the gold on Livengood Creek. Gold ranging from light yellow to a very dark iron-stained color is present; well-rounded and angular gold is found at places on the same claim; the gold on some claims is porous and on others dense; and both fine and coarse gold are often uncovered together. The coarse gold is darker, much of it being covered with a dark iron stain, and is localized in small spots. Pieces of gold worth $50 are the largest so far found on the creek. These differences in character are due largely, it is believed, to the fact that tributary auriferous channels entered the main Livengood channel from the south and contributed gold of various sorts. In support of this idea, it was noticed that the gold above Amy Creek is more uniform in character. At the lower end of the Livengood bench channel also there is a tendency toward greater uniformity in the gold, due presumably to stream sorting. Certain differences in the gold are also due to the fact that the underlying bedrock is mineralized in places, as indicated by pyritization.

The following table comprises all the information available at the present time regarding the value of the gold on Livengood Creek:

Value of gold on Livengood Creek.

Sample.	Fineness.		Value per ounce.		
	Gold.	Silver.	Before melting.	After melting.	Net value after deducting assay and exchange charges.
1				$18.92	
2	0.9175	0.078	$18.60	19.00	$18.14
3	.914	.075	18.17	18.93	17.72
4					17.75
5	.9225	.068	18.55	19.10	18.09
6	.9075	.0825	18.27	18.80	17.82
7				18.63	
8					18.00
Mean	.915	.076	18.40	18.90	17.92

It will be noticed that the Livengood gold is of high grade. The mean value of the Fairbanks gold[1] is given as $17.73, but this figure is derived in part from values given for "crude dust" and for the gold after melting, both of which are considerably higher than the "net value." Yet the Livengood gold is worth 19 cents an ounce more than the admittedly high value given for the Fairbanks gold. This difference is not due to any particular freedom from the base metals in the Livengood gold, which has an average content of 9 parts per thousand of these, compared with 5 to 10 parts in the Fairbanks gold. The higher value is due evidently to the smaller content of silver in the Livengood gold, the mean proportion being about 76 parts per thousand, compared with 82 to 172 parts per thousand in the Fairbanks gold.

The concentrates.—A study of the concentrates, or heavy sands, recovered with the gold may throw considerable light on the origin of the placers and is certain to give advance information regarding any other minerals of value likely to be found in the drainage basin of the stream that deposited the auriferous gravels. With this idea in mind, representative samples of the heavy sands were collected at eight localities from the Livengood bench channel, at more or less regular intervals from the Red claim, opposite claim No. 15 above Discovery, down to the Nelson bench, opposite Discovery claim. These samples show that magnetite, ilmenite, limonite, picotite, and hematite are universally present in the heavy sands. In addition, barite was found on the Sunnyside, Etna, Gold Dollar, Eldorado, and Nelson bench claims, and pyrite on the Sunnyside, Etna, Sunny, Gold Dollar, and Nelson bench claims.

The iron minerals magnetite, ilmenite, limonite, hematite, and pyrite are not unusual, but the presence of picotite (chrome spinel) was not expected. Its universal presence shows that considerable chromium is associated with the rocks in the basin of Livengood Creek as it existed when the auriferous gravels were laid down. In this connection it may be mentioned that chromite (iron chromate) has been found on the spur west of Ruth Creek. It seems likely that both the picotite and the chromite are associated genetically with the serpentine in the Middle Devonian rocks, which outcrop at Livengood and may be traced northwest and southeast for long distances The presence of barite (barium sulphate) is of interest. It occurs at numerous other localities in interior Alaska, among which may be mentioned Little Minook Creek,[2] in the Rampart district; Poorman Creek, in the Ruby district; and the North Fork of Hess River. Neither chrome nor barium ore, however, could be of commercial value in this district at the present time.

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[1] Prindle, L. M., and Katz, F. J., Geology of the Fairbanks district: U. S. Geol. Survey Bull. 525, pp. 113-114, 1913.

[2] Eakin, H. M., oral communication, 1917.

Mining operations.—The history of the discovery of gold placers on Livengood Creek by Jay Livengood and N. R. Hudson during the summer of 1914 has been narrated by Brooks.[1] These men, however, staked for the most part creek claims on Livengood, Gertrude, Ruth, Lillian, and Olive creeks. The richest gold-bearing gravels, on the second and third tier benches on the right bank of Livengood Creek, were staked by later prospectors, and the original discoverers of the district did not profit in fullest measure by their work.

Twenty-one plants, employing between 225 and 250 men, were at work during the summer of 1916 mining the auriferous gravels on the Livengood bench claims. The accompanying sketch (fig. 6), showing the approximate position of the bench claims, is compiled from descriptions by the miners and is not meant for an accurate chart of the placer claims. It is introduced merely to show the relative position of the different claims.

The placer mining on the Livengood bench is accomplished entirely by underground methods. A shaft is sunk to bedrock and tunnels are driven in two directions from the bottom of the shaft, along the line of the pay streak, as far as it is expected that the ground will be worked from that particular shaft. From the ends of the two tunnels crosscuts are made to the lateral limits of the auriferous gravel, and, the piece of ground to be worked having thus been blocked out, the gravel is removed by a retreating long-wall system, working toward the shaft. It is feasible to work 150 or 200 feet in either direction, and hence blocks of ground 30,000 to 40,000 square feet in extent are commonly cleaned from a single shaft.

The underground conditions for mining are excellent. The ground is solidly frozen from top to bottom. No water is present in the workings, because so far no thawed ground or underground watercourses have been encountered. The ground is therefore solid, and little or no timbering is necessary. Examination of untimbered workings a year old, from which all the gravel has been removed, show no tendency of the roof to cave. These favorable conditions have rendered mining much more economical than in the Fairbanks district.

In thawing ground in the tunnels 8-foot steam points are commonly used. These are placed 2 feet apart, thus rendering the duty of each point 4 square feet on a face, or about 1.2 cubic yards. It is estimated that 1 horsepower is required to each steam point.

After thawing, the gravel and bedrock is picked loose and conveyed by wheelbarrow to the shaft, whence it is elevated to the surface, conveyed by an overhead cable to the desired spot, and dumped from self-dumping carriers. Sluicing is carried on in the usual manner. Tailing room is usually procured by groundsluicing off a channel in the muck, in the direction of Livengood Creek, but occasionally it is necessary to elevate the sluice boxes in order to obtain sufficient grade.

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[1] Brooks, A. H., Preliminary report on the Tolovana district: U. S. Geol. Survey Bull. 642, p. 201, 1916.

Ground that is owned by the operator may be worked at a profit if it will yield 50 cents to the square foot of bedrock, and under favorable conditions and economical management ground as low in value as 35 cents to the square foot may be mined. Operations under a lease, however, must be confined to higher-grade ground, the exact value depending, of course, on the percentage due to the owner.

CREEK PLACERS.

Only one claim has thus far been worked in the present channel of Livengood Creek, and little is known of the length, width, or character of the pay streak. It was reported to the writer that material carrying 40 to 50 cents a square foot has been found at certain localities by drilling.

The claim now being worked is claim No. 5 above Discovery, at the mouth of Gertrude Creek. At this point the distance to bedrock is 16 feet, there being 6 feet of muck overlying 10 feet of gravel. The gold is in the lower 4 feet of gravel and the upper foot of decayed chert bedrock, and the tenor is reported to be higher than the figures above mentioned. The gold is said to be rough and shotty, and much pyrite is reported to occur in the concentrates. Mining is carried on by drifting operations.

Some prospecting has been done on the present stream gravels of Livengood Creek, with the idea of their possible exploitation by dredging. Much of the ground is frozen, and it seems likely that the operator of a dredge would be obliged to figure on a thawing plant in order to reclaim any large part of the gold.

Prospecting has revealed certain additional facts regarding the location of the

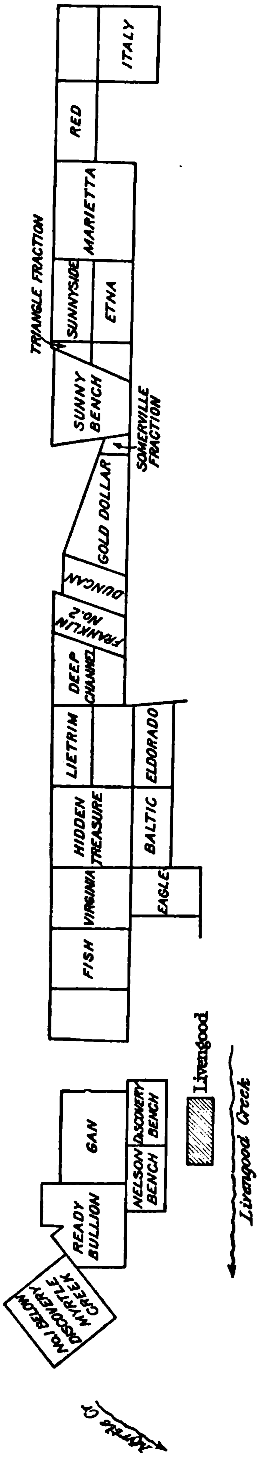

FIGURE 6.—Sketch map of placer-gold bench claims on Livengood Creek.

pay channel on the lower portion of Livengood Creek. About 1,500 feet downstream from the mouth of Ruth Creek and 300 feet south of Livengood Creek a shaft 32 feet deep showed 25 feet of muck and slide overlying 7 feet of well-rounded gravel. Another shaft 600 feet upstream and close to the present Livengood Creek exposed 28 feet of muck and slide overlying 7 feet of similar gravel. Gold is present in the lower 4 to 5 feet of gravel, as well as in 1 to 2 feet of the decayed slate bedrock. Farther downstream the depth to bedrock becomes very great.

TRIBUTARIES OF LIVENGOOD CREEK.

GOODLUCK CREEK.

No mining has yet been done on Goodluck Creek. On the fourth claim downstream from the summit at the head of the creek a shaft has been sunk 60 feet to bedrock. In this shaft 50 feet of muck is exposed, overlying 10 feet of angular wash. The bedrock is a brecciated dark-colored flint. Some flaky porous gold is obtained just above the bedrock.

About 1,500 feet farther upstream some fine gold is present in angular wash almost at the surface, being overlain by only a few feet of muck and underlain by a deep body of the same material. It appears from this occurrence that gold has been eroded from the ridge to the south and deposited comparatively recently.

The bedrock on the southwest side of Goodluck Creek is largely silicified limestone; on the northeast side flint or dark chert. There seems to be a body of greenstone, perhaps a dike, lying between these two rock formations.

AMY CREEK.

No mining has been done on Amy Creek, but a number of prospect shafts along the east side of the creek show the presence of auriferous gravels, lying on bedrock. The owners of claim No. 4 above Discovery expect to begin open-cut work during the summer of 1917, and other claims on this creek will also doubtless be worked.

Several different kinds of bedrock are present in the basin of Amy Creek. The main bedrock is chert, but at the mouth of the second tributary on the east side, above Livengood Creek, a body of albite granite crops out, and it continues apparently eastward to the top of the ridge. At the extreme head of Amy Creek basalt porphyry occurs with the chert, and at the lower end some limestone is present on the west side and in the bedrock under the gravels. At the mouth of the creek the limestone is succeeded by graphitic argillite, similar to the bedrock on the Marietta bench claim.

It is believed that Amy Creek has been an important contributor to the gold content of the Livengood bench and stream gravels. It must also have contributed considerable gold to the basin of the

South Fork of Hess River, at the time when it was tributary to that stream.

LUCILLE GULCH.

One or two prospect shafts have been sunk on Lucille Gulch, but no work was in progress during the summer of 1916. It is reported that prospecting will be continued.

GERTRUDE CREEK.

Discovery claim, at the mouth of Gertrude Creek, was being groundsluiced in August, 1916, preparatory to the beginning of open-cut placer mining. A dam has been constructed upstream to provide a water supply for sluicing. The depth to bedrock is about 25 feet at this point. The thickness of gravel is 14 feet, of which the upper 12 feet will be groundsluiced off with the overlying muck, and the lower 2 feet will be run through the sluice boxes.

The bedrock is chert. A specimen of the concentrates collected with some gold from this locality shows the presence of magnetite, ilmenite, picotite, and pale-yellow zircon.

About a mile from its mouth Gertrude Creek is formed by the junction of two forks, the eastern one of which is known as Glen Gulch. Discovery claim, at the lower end of Glen Gulch, was being worked by open-cut methods in 1916. The cut showed from 2 to 4 feet of gravel, covered by 10 to 25 feet of muck. The bedrock is silicified limestone. The gold is fine, angular, and shotty, although pieces worth $1 have been found.

RUTH CREEK.

Open-cut work was begun at the lower end of Discovery claim, Ruth Creek, during the spring of 1916. The bedrock is a black, finely crystalline limestone, much seamed with calcite and quartz. This is overlain by 5 feet of gravel, which is covered by 12 feet of muck and slide. Farther up on the same claim the depth to bedrock is much less. The gold lies in the gravel and in 2 feet of bedrock. The gravels are angular and comprise chert conglomerate, chert, sandy shale, diorite, and other rocks. The pay streak, so far as known at present, is 30 to 40 feet wide. The gold is of high grade, netting $18 an ounce or more after deducting all charges. It is partly rough and partly well worn. The largest piece so far found is worth $3. At present the gravel is shoveled into the sluice boxes. Later a ditch will be dug around to Gertrude or Amy Creek, and a hydraulic plant may be installed. Four men were at work on this claim at the time of visit, but probably more were employed later in the season, when the supply of water became adequate.

On the lower end of claim No. 3, above Discovery, two men were sinking a shaft to bedrock, with the intention of drifting, hoisting, and sluicing.

Upstream on the same claim another operator has sunk a shaft to bedrock, a depth of 20 feet, and was also planning to drift and sluice. At this point on Ruth Creek the surface of the bedrock appears to dip away from the creek on each side, so that there are two deeper auriferous channels. Evidently superposition of drainage, due to the general process of silting already described, has occurred on the tributaries of Livengood Creek, as well as on the main stream.

Preparations are also being made to do placer mining in claim No. 4, above Discovery, where the depth to bedrock ranges from 5 to 18 feet. Some of the ground will be mined by drifting and some of it by open-cut work.

LILLIAN CREEK.

Mining operations by open-cut methods were in progress on two claims on Lillian Creek, Nos. 1 and 2, above Discovery. Both stream and bench placers have been worked, but the creek is so small that operations of both types have been done on creek claims.

On claim No. 2, where the writer obtained most of his data, sufficient work has been accomplished to show the general character of the pay streak, which is well developed in the present creek but slopes away into the hill on the south side, thus grading into an older channel. The width of this pay streak is at least 168 feet, but its extent downstream is not known. On the north wall of the creek another pay streak, 100 feet wide, is present on a bench about 60 feet above the creek and sloping toward it. This bench and its auriferous gravels appear to continue downstream into the adjoining claim, No. 1 above Discovery.

In the creek where the present work is being carried on there is an overburden of 4 to 5 feet, covering about 18 inches of gold-bearing slide gravel, which overlies the bedrock. Farther south, in the slope of the hillside, the depth to bedrock is 30 feet, the lower 15 feet of which is gold-bearing gravel. The gravels in general are angular to subangular and are composed of conglomerate, greenstone, and a variety of sedimentary rocks, including sandstone, shale, slate, and quartzite. The bedrock is chiefly sandstone and shale, with some slate, and is commonly mineralized with pyrite. Gold occurs in all the gravels and in 1 foot of bedrock. The gold is angular, coarse, and even grained. It is said to render a net return of $17.50 to $18 an ounce.

The concentrates taken with the gold on this claim are most remarkable on account of the variety of minerals they contain. The following minerals, named roughly in their order of abundance, have been identified: Magnetite, ilmenite, picotite, limonite, cinnabar, scheelite, zircon, pyrite, stibnite, and barite. The presence of picotite is not surprising, in view of its universal presence in Livengood Creek, but this is the only creek in this district from which scheelite (calcium tungstate) and stibnite (antimony sulphide) have been taken. Cinnabar (mercury sulphide) is also present on Olive and Ester creeks, and is reported from the head of Ruth Creek but is nevertheless also worthy of special mention. A vein of stibnite is reported to have been uncovered in the mining operations. The head of Lillian Creek is only a short distance above this claim, and it follows that neither these heavy minerals nor the gold has traveled very far downstream. This is also shown by the angularity of the gold. It is judged from the presence of so many minerals in the concentrates that the mineralization at the head of the creek may be very complex in character.

The present work in Lillian Creek is accomplished by open-cut methods, the gravel being shoveled into sluice boxes. Two small dams have been used to store water for use in the bench and creek mining, but a ditch has recently been completed, which will deliver water from the Olive Creek slope, with a pressure of 200 feet, and a hydraulic plant is being planned.

The present work on claim No. 1 above Discovery, is being done on the bench gravels on the north side of the creek, where there appears to be about 6 feet of auriferous gravel, overlain by 2 to 3 feet of muck. The bedrock slopes toward the creek, as on the adjoining claim upstream. The gold is distributed in the gravel and in 6 inches to 1 foot of bedrock.

The value of the ground on the two claims on Lillian Creek is rather higher than that in the other tributaries of Livengood Creek. In fact, this ground compares favorably in value with some of the Livengood bench placers.

TRIBUTARIES OF TOLOVANA RIVER.

OLIVE CREEK.

On Discovery claim on Olive Creek three men were engaged in open-cut mining during the seasons of 1915 and 1916. At this locality the pay streak is known to be 300 feet wide, of which 100 feet was planned to be worked. The material overlying the bedrock consists of angular to subangular slide gravel, having a thickness of 10 feet or more. There is no overlying muck. These gravels consist of black flint, argillite, coarse-grained granitic rock, diabase, green flinty mineralized rock, quartzite, and chert conglomerate. The bedrock is a dark impure sandstone. The gold is distributed mainly in the lower 7 feet of gravel, though it has been noted that certain horizons in the gravel were particularly productive.

The gold is rough and unworn and is also very fine, no pieces of a value exceeding 15 or 20 cents having been found. The gold has a net value of $18 an ounce, after deducting all charges. The concentrates taken with the gold include magnetite, ilmenite, cinnabar, picotite, and limonite. Cinnabar is plentiful.

The ground is frozen, but it is opened up and allowed to thaw naturally. The thawed ground is washed into the cut by a hydraulic nozzle and directed into the sluice boxes by means of shear boards. The stream of water also aids materially in the process of thawing. Water is obtained from Ester Creek by means of a ditch. When water is scarce a dam in Olive Creek is used, which supplies enough water for ten minutes' sluicing.

On claim No. 2 below Discovery two men were opening a 4,000-foot cut, 60 feet wide at the upper end and 30 feet wide at the lower end, which was intended to be sluiced. The pay streak here is at least 350 feet wide. There is 14 feet of gravel at the surface, all of which carries gold. Under the gravel is a seam of clay, and between the clay and bedrock about 80 feet of barren muck. A little coarse gold is found at bedrock, but not enough to warrant the removal of the overlying muck, or to pay the expense of drift mining. Only the upper 14 feet of gravel will be mined.

ESTER CREEK.

Prospecting and mining in a small way was being carried on by two men on a fractional claim above Discovery, on Ester Creek. The pay streak has not yet been definitely located, but the owners believe they are on the edge of it. Conditions are similar to those on Olive Creek, but the distance to bedrock is 20 feet, and the work is being accomplished by drifting from the bottom of a shaft. The bedrock here is flint. About 3,000 feet downstream the depth to bedrock drops rather abruptly to 90 feet.

The gold recovered is said to assay $18.85 an ounce after melting. The concentrates taken with the gold include magnetite, ilmenite, picotite, cinnabar, limonite, and zircon.

SOUTH FORK OF HESS RIVER.

Prospecting has been carried on for two years on the South Fork of Hess River and its tributaries, but so far no continuous pay streak has been located, though fairly productive pockets of gold have been found in the gravels at several localities. In the light of the drainage history of this district this condition is not surprising nor difficult to understand. The South Fork in its earliest history flowed in the same direction as at present but included also the present headwater tributaries of Livengood Creek. During that period doubtless considerable gold was carried into the drainage system of the South Fork from the ridge south of Livengood Creek, which appears to be the source of most of the gold in this vicinity. Subsequently, however, Livengood Creek tapped the Hess River drainage system, and a rock divide was established in Hess River east-northeast of Livengood Dome. After this divide was established most of the gold previously washed down into the South Fork was retransported into Livengood Creek and concentrated in the present bench channel. At a still later date, after the period of silting, the South Fork reclaimed much of its former drainage basin but did not succeed in reclaiming Goodluck, Amy, Wonder, and Heine creeks and has therefore obtained gold only by means of Goldstream Creek and from the erosion of any auriferous bedrock in its basin. From the reported presence of small amounts of gold on Alabam and Moose creeks, it seems probable that mineralized bedrock must exist in the drainage basins of these streams but the extent of such mineralization and its potential significance in the formation of commercial placers in these and other tributaries of the South Fork remain to be proved. It seems to the writer that there would be more probability of finding commercial placers on the benches in the upper part of Goldstream Creek than farther downstream.

GOLD LODE PROSPECTS.

At the heads of Ruth, Lillian, and Olive creeks a group of lode claims have been located. Two men, interested in 16 of these claims, have been engaged for over a year in prospecting and have done a certain amount of development work.

On the spur west of Ruth Creek, at an elevation of about 1,400 feet, a mineralized area begins that extends southward to the top of the spur, a distance of several hundred feet. In this area quartz stringers are numerous, most of them striking from S. 20° E. to S. 60° E. Such veinlets are as a rule nearly vertical, but at one locality they dip steeply to the west. They range from a fraction of an inch to 2 or 3 inches in width and are mineralized with pyrite, arsenopyrite, and gold. Some of them are reported to carry as much as $12 to the ton in gold and $2 to the ton in silver, but the average value would probably be much lower. Calcite veins carrying some gold and sulphide minerals are also present. These apparently cut the quartz veins and are therefore later.

Where the quartz stringers have been exposed there is commonly also an intensely mineralized zone on both sides. Thus at one locality about halfway up the spur, a quartz vein 1 inch thick is bordered by such a zone of mineralization, which extends on each side for a distance of 18 inches, gradually merging into the country rock. This zone is in part much decayed and in part a hard green-stained rock, composed of a mixture of crystalline dolomite, quartz, calcite, and sulphides. The green material is plainly an oxidation product, derived from numerous grains of chromite that are scattered throughout the mineralized rock. It may be mariposite, a chromiferous chlorite.

The country rock on this spur is a part of the Middle Devonian stratigraphic sequence and hence is made up of many rock types, including sandstone, shale, slate, quartzite, crystalline limestone, and dolomite, as well as a variety of intrusive rocks. The more intense mineralization so far discovered appears to have been localized in and near the quartz veins, but diffuse mineralization has occurred in much of the surrounding country rock. Considerable white opaque quartz is also present on this spur, but it seems to have no genetic connection with the gold, and is mineralized only where it occurs near the mineralized zones above described. A soda rhyolite porphyry, which intrudes the country rock near the upper end of the mineralized area and is itself heavily mineralized and veined with quartz, is believed to have a genetic connection with this lode deposit. At the upper end of this spur, on Money Knob, the country rock is greatly sheared and shows a well-developed vertical cleavage striking S. 20° E. This rock also is diffusely mineralized.

As far as may be judged from the present developments, a large body of rather low grade gold ore is present in the lode at the heads of Ruth, Lillian, and Olive creeks. It is unlikely that under present conditions this lode as a whole can be worked at a profit; but more development work may reveal zones of higher-grade ore that might possibly be worked, even under present conditions.

The presence of chromite within this area of mineralization is particularly worthy of note. One small excavation at the surface has exposed a body of chromite, but neither the extent of the deposit nor its relation to the surrounding rocks is apparent from the small amount of work done. It is believed that the chromite has a genetic connection with bodies of serpentine in this vicinity and its presence in association with the gold is therefore regarded merely as a fortuitous circumstance. It appears, however, that the gold-bearing solutions have dissolved and redeposited some of this chromite, as is indicated by the presence of its oxidation products in the mineralized zones near the quartz veins.

On the south side of the ridge between Livengood Creek and Tolovana River, on the headwater slope of Olive Creek, a small landslide has exposed a body of much weathered granitic rock, from which cinnabar was panned.

MINERALIZATION.

There can be little doubt that the mineralization that produced the placers on Livengood Creek was localized mainly on the ridge between Livengood Creek and Tolovana River. The presence of gold in all the streams draining this ridge and its absence in the other tributaries of Livengood Creek afford sufficient proof of this general statement. The occurrence of intense mineralization in the lode deposit at the heads of Ruth, Lillian, and Olive creeks serves as corroborative evidence.

There remains, however, the question of the outer limits to which the mineralization extended. The pyritized condition of the bedrock underlying the bench placers at certain claims on Livengood Creek is essentially similar in nature, though more diffuse, than the mineralization at the gold lode above referred to. It seems probable, therefore, that north of the ridge the bench placers of Livengood Creek may mark the outer limits of mineralization. It is believed, however, that only a very small amount of the Livengood bench gold was residual—that is, derived from the weathering of the underlying bedrock. All the evidence goes to show that it has been transported some distance to its present position.

The presence of a small amount of gold in the upper drainage basin of the South Fork of Hess River and in Moose Creek lends strength to the belief that a diffuse phase of the same mineralization may have extended a considerable distance to the east and northeast. The regional trend of the rock formations lies in this direction, and if, as seems probable, the mineralization was related to structural features, it is not to be expected that the mineralizing effect would be sharply delimited in this direction. Yet in the course of a traverse around the head of the South Fork drainage basin the writer was unable to see any indication of intense mineralization along the ridge tops, nor any bodies of acidic intrusive rocks that would indicate the presence of a gold mineralization. This information, however, is by no means conclusive evidence of the absence of commercial gold placers in that area, for the valleys are wide, and a traverse along the ridge tops represents only a hasty examination of a small area. Nevertheless, the writer is inclined to believe that the more intense phase of the gold mineralization was confined to the ridge between Livengood Creek and Tolovana River.

To the south of this ridge the mineralizing effect is probably rather sharply delimited, as to the north. That this is true is indicated by the failure of the gravels of Steel Creek (south of Tolovana River) to become productive placers, as expected. To the west and southwest, in the Tolovana Flats, the bedrock lies at a great depth, and the continuation of this zone could lie in the basin of the West Fork of Tolovana River. Whether other gold placers lie in that direction has not yet been proved.

The close relation between the mineralization in the vicinity of Livengood Creek and the regional structure is well shown by the geologic map. The regional structural trend in this district is about N. 60° E., but it will be noticed that in the area of the mineralization there is a marked flexure in the rock formations, resulting in the development of a well-defined cross structure that trends about

N. 60° W. The ridge northwest of Amy Dome reflects this structure in its direction of elongation, as does also the contact between the Middle Devonian rocks and the chert formation in the same vicinity. The presence of these two major tectonic lines has also determined the course of Tolovana River, which for 11 or 12 miles flows in a general westerly direction. The valley of upper Livengood Creek also shows a tendency toward a westerly elongation.

The lode deposit above described also shows a structure at variance to the regional structure. The quartz veins have a general strike ranging from N. 20° W. to N. 60° W., and the mineralized country rock has been sheared in a northwesterly direction, to the extent of developing locally northwesterly a cleavage.

The immediate cause of the gold mineralization in the vicinity of Livengood Creek is related to the intrusion of igneous rocks, with the subsequent migration of mineralizing solutions therefrom. Igneous rocks of several kinds occur on the ridge between Livengood Creek and Tolovana River, and the relations existing between the different types are obscure. Consequently, to an even greater extent, are the mineralizing processes difficult to decipher. Certain observed facts, however, have influenced the writer to the belief that the gold mineralization had a more intimate genetic connection with the more acidic types of intrusive rocks on this ridge. One of these facts is the intimate association of soda rhyolite porphyry with the lode deposit and the heavy mineralization of that rock; the second is the presence of cinnabar in decayed granitic material at the head of Olive Creek; and the third is the presence of the conspicuous body of albite granite in the basin of Amy Creek.

Even if the assumption of this genetic association is correct, there yet remain other puzzling features. First of all, there seems to be considerable diversity in the mineralizing effects within the same zone. At the west end of the mineralized ridge cinnabar is present in the concentrates from three creeks, and stibnite and scheelite in the concentrates from one of these creeks; yet at the east end of the same ridge none of these minerals have been reported, and even if they are present they must occur in minor amounts. The type of occurrence at the west end of the ridge suggests a certain similarity to the type of mineralization prevalent in the Iditarod district. Yet no residual placers occur here, as at Iditarod, and the gold mineralization seems to have been connected directly with quartz veins, and only indirectly with the acidic intrusives. The mineralization at the east end of the ridge, however, with the lack or paucity of cinnabar in the concentrates, seems to resemble more nearly the Fairbanks type. Finally, the total absence of cassiterite everywhere in the Tolovana district tends to show that this mineralization is entirely different from the Hot Springs type.

With these anomalous features in mind, the writer does not feel warranted in making any very definite statements regarding the geologic age of the Livengood mineralization, nor regarding its correlation with the mineralization at localities near by. The presence of stibnite, and particularly cinnabar, is interpreted as indicating a Tertiary age for at least a part of the gold deposition, but it seems entirely possible that such an area, characterized by divergent structure and igneous intrusion, might have been subjected to mineralizing effects at more than one period in geologic time. The occurrence of chromite and chrome spinel in the district has a bearing on this point. These two minerals are with little doubt connected genetically with the bodies of serpentine in the Middle Devonian rocks near Livengood, and the serpentine is interpreted as evidence of Paleozoic volcanism. It is not unlikely that this locality was a zone of weakness and a site of chromium mineralization during Middle Devonian time. If this is true, it would not be unreasonable to infer that such a zone of weakness may have been localized in this particular area for geologic ages. The possibility therefore remains that the Livengood mineralization is composite in character and represents the total effect of more than one period of mineralization.

MINERAL RESOURCES OF THE KANTISHNA REGION.

By Stephen R. Capps.

INTRODUCTION.

The region discussed in this report lies on the north side of the Alaska Range and includes portions of the basins of Nenana and Kantishna rivers. (See Pl. XV.) It includes the southern portion of the Tanana lowlands and some of the outlying mountain ridges, though nowhere reaching the crest of the range, and lies between meridians 149° and 151° 10′ west longitude, and parallels 63° 25′ and 64° 15′ north latitude. Figure 7 shows the relation of this area to surrounding portions of Alaska.

The discovery of gold in the Canadian Klondike and the consequent influx of prospectors and miners resulted in the beginning of systematic exploration in this region. The first accurate surveys in this vicinity were made in 1898, when two United States Geological Survey parties reached the Alaska Range. One of these parties, conducted by George H. Eldridge and Robert Muldrow, ascended Susitna River and crossed the divide to the head of Nenana River. The other party, in charge of J. E. Spurr and W. S. Post, ascended to the head of Skwentna River, crossed the Alaska Range, and descended the Kuskokwim. Thus some of the major features of the range were outlined, although neither of these parties reached the region here discussed. The first survey to be extended to the Kantishna region was made in 1902, when a Geological Survey expedition under the leadership of A. H. Brooks and D. L. Reaburn proceeded from Cook Inlet to the head of the Skwentna, crossed the Alaska Range, and traversed the northwest flank of the range as far eastward as Nenana River, thus crossing the region from west to east. In 1903 and 1904 the great gold rush to the Fairbanks district took place and prospecting was stimulated throughout the Tanana Valley. In 1905 gold placer gravels were discovered in the Kantishna Hills, north of Mount McKinley, and several thousand gold seekers came to the scene of the new diggings. Most of these were disappointed, but a few located paying ground, and the district has been producing since that time. Furthermore, within the last few years a number of promising gold lodes have been found in the

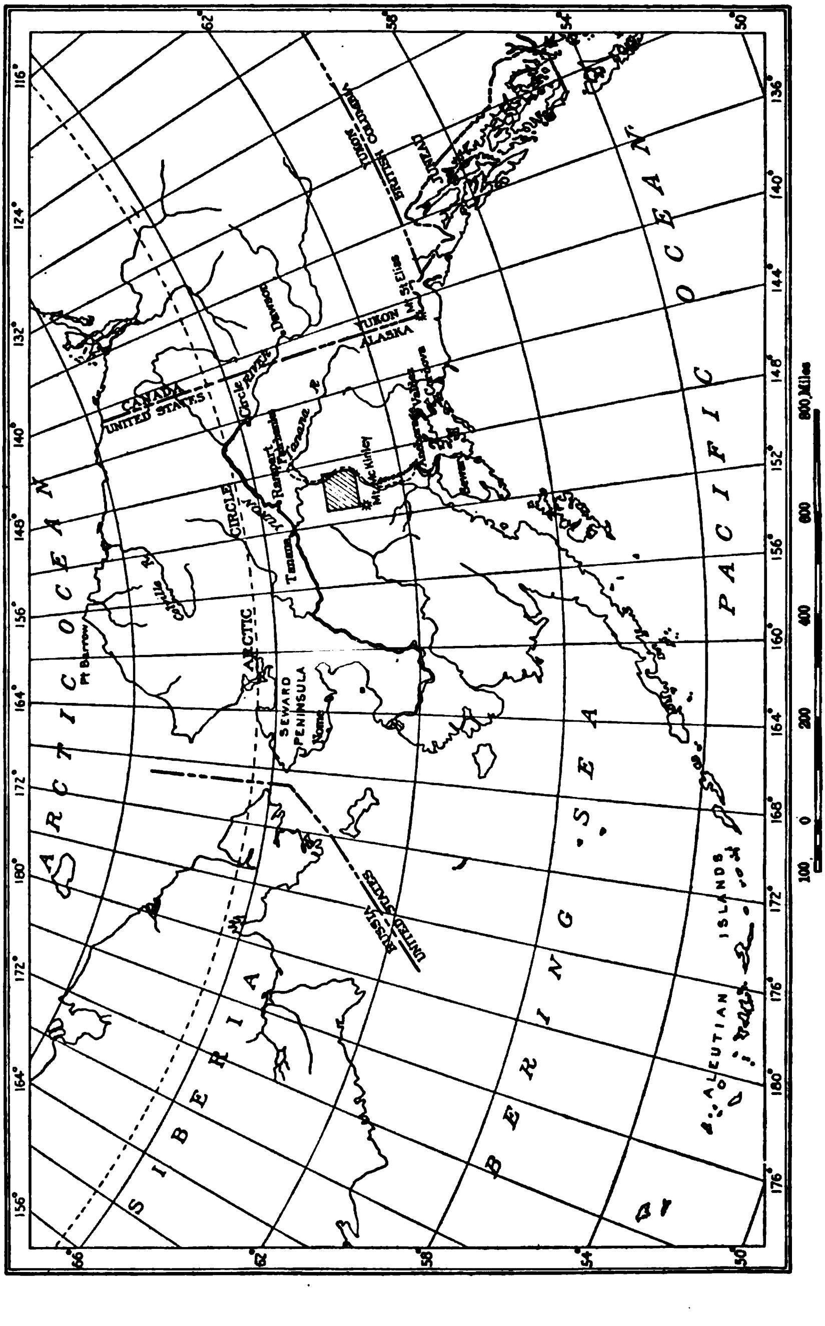

FIGURE 7.—Index map showing location of the Kantishna region.

district. The beginning of vigorous construction work on a Government railroad from Seward to Fairbanks, by way of the Susitna and Nenana valleys, has made it likely that many mining claims in the Kantishna district which were not worked under the old conditions of difficult access and costly transportation will become valuable, and a demand has arisen for more detailed and more recent information about the region than was available. Accordingly two parties were sent to this field in 1916 to extend the topographic and geologic mapping. The topographic party, in charge of C. E. Giffin, commenced work on Nenana River at the mouth of Dry Creek and carried the mapping westward to include the Kantishna mining district. The geologic party, in charge of the writer, covered much the same ground, and at the end of the season several weeks were spent in a study of the placer and lode deposits of the Kantishna district.

Before this work was commenced a general knowledge of the geology of the region had been gained by earlier expeditions. In 1902 Brooks[1] and Prindle had crossed the region and had mapped the surface distribution of the various formations along this route. In 1906 Prindle[2] again made a hasty trip to the then newly discovered Kantishna diggings. In 1910 the writer[3] mapped an area between Nenana and Delta rivers, adjoining this region on the east. Detailed reference to the work of these geologists will be made in a more complete report on this region, now in preparation, but full use has been made by the present writer of their published and unpublished notes. Especial acknowledgment is due to the pioneer work of Brooks and Prindle, for they recognized and outlined all the major rock formations and in the almost complete lack of fossils from this area it is largely on the basis of their observations that the age of several of the formations is determined.

The conclusions reached in this paper and the distribution of formations shown on the accompanying geologic sketch map (Pl. XV) are the result of a merely preliminary study of the material at hand and are subject to modifications in the fuller report.

GENERAL FEATURES OF THE DISTRICT.

GEOGRAPHY.

Few areas in the world exceed in scenic grandeur the Alaska Range in the vicinity of Mount McKinley. That mountain itself, having an elevation of 20,300 feet, is the loftiest peak in North America, and with its companion peak, Mount Foraker, can be seen from Yukon River, on the northwest, to Cook Inlet, on the south. Although both of these impressive ice domes surpass by several thousand feet the highest of their neighbors, they stand amidst a multitude of rugged and magnificent mountains. The line of perpetual snow lies at an elevation between 6,000 and 7,000 feet, and above it all surfaces not too steep to hold snow are buried beneath an icy covering. From this mountain mass great glaciers descend all the larger valleys to the mountain front, and the crest of the range is therefore inaccessible except to the man who is willing to endure the hardships of alpine work. In the winter of 1916 Congress passed an act to establish the Mount McKinley National Park, containing an area of about 2,200 square miles, and thus preserved for the people the mountain scenery and the prolific herds of wild game that have made the north slope of this part of the Alaska Range notable. With the completion of the new Government railroad this national park will become accessible and will afford a splendid area for study and recreation in the midst of America's most inspiring natural surroundings.

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[1] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, 1911.

[2] Prindle, L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, pp. 205–226, 1907.

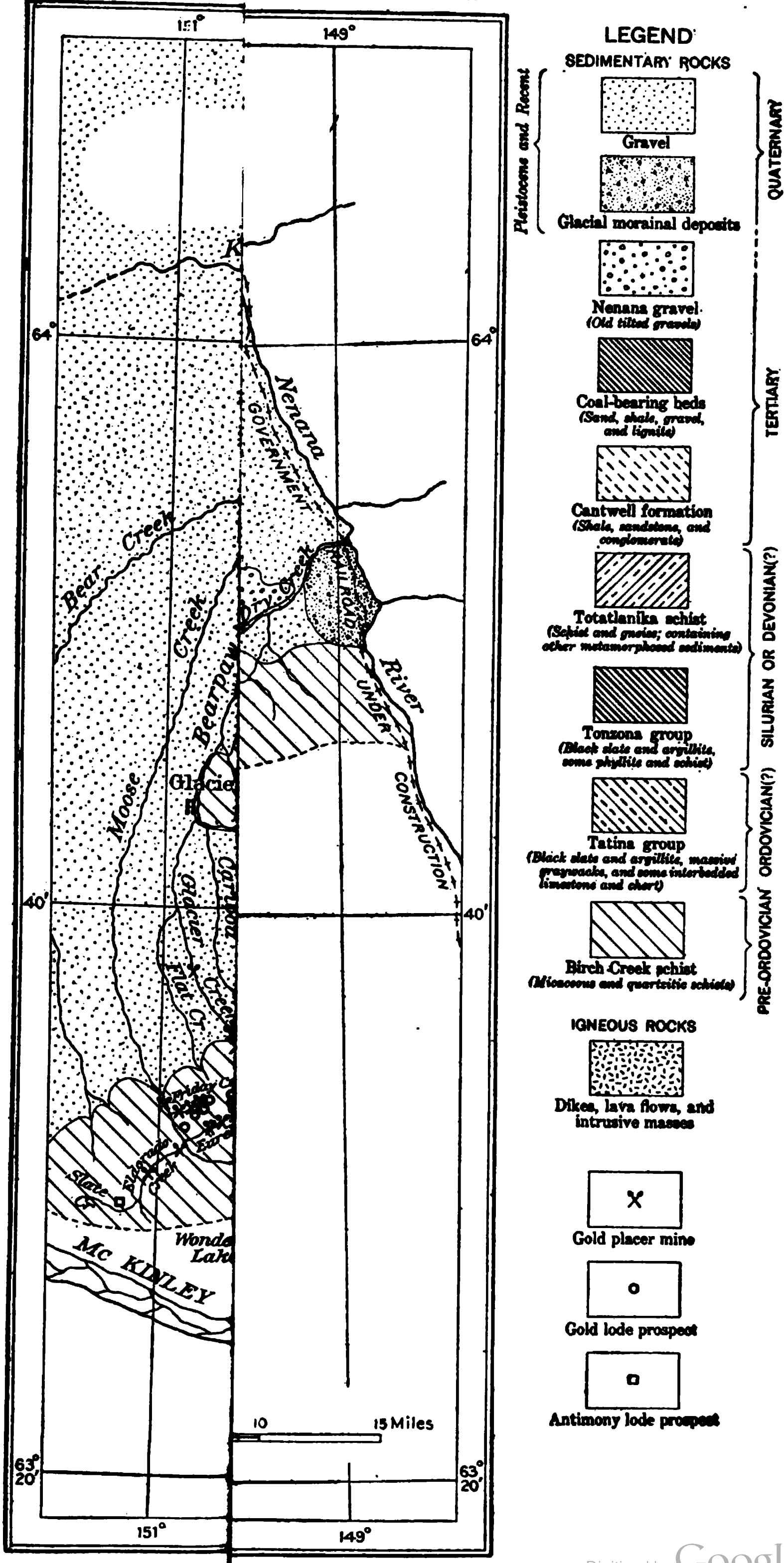
[3] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, 1912.

Only a small part of the main Alaska Range is included in the area here described, but plans are under way to extend the geologic and topographic mapping to include the main range from Broad Pass to Mount McKinley and the northwest face of the range for some distance southwest of the mountain. The area here described comprises some of the long mountain ridges that extend northward from the crest of the range; several subsidiary mountain ridges that lie north of and parallel to the main range; the so-called Kantishna Hills; and the low, basin-like areas that lie between and north of the foothill ranges.

Two large streams, Nenana and Kantishna rivers, both tributaries of the Tanana, receive the drainage from this region. Nenana River borders the area on the east, and to it Teklanika River, which drains the eastern portion of the area, is tributary. Kantishna River drains a wide area west of the Nenana Basin and within the region here described is fed by Toklat River and its glacial waters and by the clear waters of Bearpaw River, draining the north and west slopes of the Kantishna Hills.

GLACIATION.

The higher portions of the Alaska Range constitute the feeding ground for many glaciers, and an ice stream is to be found in the head of almost every valley that drains from the divide. These glaciers are smallest where the mountains are low, but from the loftier portions of the range great valley glaciers flow down radially


151°
149°
64°
40'
63° 20'
K
Nenana
GOVERNMENT
RAILROAD
UNDER
CONSTRUCTION
River
Bear Creek
Dry Creek
Bearpaw
Moose Creek
Glacier
Glacier
Flat Cr.
Caribou Creek
Friday Cr.
Eureka
Eldorado Creek
Slate Cr.
Wonder Lake
Mc KINLEY
10
15 Miles
LEGEND
SEDIMENTARY ROCKS
Pleistocene and Recent
QUATERNARY
Gravel
Glacial morainal deposits
Nenana gravel (Old tilted gravels)
TERTIARY
Coal-bearing beds (Sand, shale, gravel, and lignite)
Cantwell formation (Shale, sandstone, and conglomerate)
SILURIAN OR DEVONIAN(?)
Totatlanika schist (Schist and gneiss; containing other metamorphosed sediments)
Tonzona group (Black slate and argillite, some phyllite and schist)
ORDOVICIAN(?)
Tatina group (Black slate and argillite, massive graywacke, and some interbedded limestone and chert)
PRE-ORDOVICIAN
Birch Creek schist (Micaceous and quartzitic schists)
IGNEOUS ROCKS
Dikes, lava flows, and intrusive masses
Gold placer mine
Gold lode prospect
Antimony lode prospect

SKETCH [illegible] PROSPECTS.

in all directions. Glacial ice is most abundantly developed on the southeast slope of the range, as the precipitation is heavier on that side than in the Tanana Basin, and the glaciers that drain to the Pacific are thus much larger than those whose waters flow to Yukon and Kuskokwim rivers. In the area here described there are no large glaciers, but the streams that cross it are fed from the melting ice fields and carry abundant débris supplied by the ice tongues. The present glaciers are, however, of small size compared to the ice streams that in times past flowed northward from the range far out into the foothills. That greater glaciers were formerly present is now to be recognized by the shape into which they eroded their beds and by the deposits of glacial débris they laid down in moraines and as glacial outwash gravel. The influence of the ice advance was thus felt far beyond the borders of the glaciers themselves, for the turbid streams built up valley deposits of glacial gravels that extend many miles north of the area that was actually covered by ice.

ROUTES OF TRAVEL.

The remoteness of the Kantishna region from established lines of transportation has made travel to it difficult and the transportation of supplies expensive. Even the mail arrives at very irregular intervals, for no mail route to the mining district has been established and mail is brought in only by courtesy of the chance traveler. Often the camp is isolated from communication with the outside world for weeks or months at a stretch. During the season of surface mining in summer the miners are busily engaged in working their ground and rarely make trips to Tanana River, the nearest line of communication.

Fairbanks has, until 1916, been the center of supplies for the Kantishna district, and most of the supplies taken to the mines have been hauled in from Fairbanks in the winter by dog sleds. The customary route followed Tanana River down to the mouth of the Nenana, ascended that stream to the base of the foothills, a distance of 30 miles, and thence proceeded westward along the base of the foothills to Knight's roadhouse on Toklat River, north of Chitsia Mountain. The trail then followed up the Toklat and its tributary Clearwater Fork to Myrtle Creek, up Myrtle Creek and across a low divide to Spruce Creek, and down that stream and Moose Creek to the mines on Moose Creek and its tributaries. The total distance by this route from Fairbanks to Moose Creek at the mouth of Eureka Creek is about 165 miles. Now that the town of Nenana has been established at the mouth of Nenana River it is likely that many of the supplies for the mines will be purchased at Nenana and the sled haul shortened by 55 miles.

Summer travel to the Kantishna region goes almost exclusively by boat. The regular river steamboats run to the mouth of Kantishna River, and shallow-draft launches may be used to ascend that stream and its tributary, Bearpaw River, to the head of navigation at Diamond. From Diamond it is necessary in summer to go afoot to the mining claims, and in winter dog sleds are used. It is also possible to take launches up Kantishna River to McKinley River, and up that stream to the abandoned town of Roosevelt, which is about as distant as Diamond from the mines on Eureka Creek. The route overland from Roosevelt lies through a country that is swampy in the summer, and this route has been little used in recent years.

It has been the prevailing custom for each miner to bring in his own supplies early in the spring by dog sled, so that no commercial rate for winter freighting is definitely established. Some provisions, especially those of the kind that are damaged by freezing, have been brought from Fairbanks to Diamond by launch in summer at a freight charge of 4 to 6 cents a pound.

Summer travel to the parts of this area other than the immediate vicinity of the mines is negligible. During the season's field work between Nenana River and the Kantishna mining district the Survey parties encountered no one and found no evidence that anyone had been there recently. No summer trails were seen, although a number of trappers' cabins and tents indicate that a few men spend their winters in trapping and hunting within the area. The country is, however, easily passable in summer for pack horses. The gravel bars of the larger streams afford firm footing for horses, and there are many low divides through the north-south ridges, so that it is easy to pass from one stream basin to the next. To one who is familiar with the difficulties of summer travel in many other parts of Alaska this region offers a pleasant relief from boggy ground and brush.

VEGETATION.

Much of this region lies above timber line. The Tanana lowland is dotted with marshes, interspersed with patches of small timber, including spruce, birch, tamarack, and cottonwood; the spruce greatly predominates over the other varieties. The heaviest stands of timber appear in the better-drained areas, particularly along the banks of the streams and on the lower slopes of the hills. Along the larger valleys the timber reaches farther south into the mountains. Thus in the Nenana Valley timber extends southward beyond the area included in this report. Savage River has spruce as far south as the head of its upper canyon. The valleys of Sanctuary River and the Teklanika have some timber within 10 or 15 miles of their heads, and Toklat River and its East Fork have trees along the lower flanks of the mountains equally far south. Stony Creek is timbered to the mouth of Boundary Creek, and Moose Creek to the mouth of Willow Creek. In general, timber extends up the valleys to elevations between 2,500 and 3,000 feet, though exceptionally stunted spruce trees may be found at an elevation of 3,500 feet or more. In practically all the valleys willow bushes of sufficient size to furnish tent poles and firewood may be found above the last timber.

Grass for forage is generally obtainable in all parts of the area where timber or brush for camping purposes are to be found. A certain variety of vetch that grows on the stream gravel bars is also eagerly eaten by horses after the seed pods have formed. During the summer, therefore, horses will do well if allowed sufficient time for grazing and unless the work required of them is too severe. With the advent of heavy frosts in the fall, however, the vegetation loses its nutritive qualities, and horses must be supplied with hay and grain if they have to do heavy work. In other parts of interior Alaska where climatic conditions appear to be equally severe horses have passed the winter successfully without being fed or cared for in any way. Although the experiment has not been tried in this area, it seems likely that in the more favorable places horses would winter if they were turned out in good condition.

GAME.

The north side of the Alaska Range west of Nenana River is remarkable for the abundance and variety of its big game. Probably no other area in Alaska is so well stocked with sheep, caribou, and moose. The white mountain sheep are confined to the main range and the more rugged foothills, but within their chosen area they may be seen daily in large bands. Caribou are present both in the mountains and in the foothills. East of the Toklat basin a few were seen, but in the valley of the main Toklat and westward to Muldrow Glacier they were especially abundant, in herds some of which contained hundreds of individuals. Moose are present in all the timbered areas, and their range thus lies north of the principal feeding grounds of the sheep and caribou. Black bears are also distributed throughout the timbered districts, and grizzly bears range the area above timber line. Rabbits and ptarmigan are abundant in some years, but few were seen during the summer of 1916. A considerable number of fur-bearing animals, notably fox, lynx, mink, and marten, are captured each winter. Beaver are especially numerous in the lowlands.

NATIVES.

There are no settlements of natives in the region here considered. The Indians of interior Alaska depend upon fish for the main item of diet, both for themselves and for their dogs, and consequently have their permanent villages at places where they can most easily obtain fish. The principal native settlements nearest this area are a large village on Tanana River about a mile above the mouth of Nenana River; another at Tanana, on Yukon River; a small settlement on Lake Minchumina; and another at Telida, on the upper Kuskokwim. Natives from these villages occasionally journey to the mountains on trapping or hunting trips, but as they are able to kill moose in the lowlands, nearer their settlements, they spend little time in the mountainous country.

GENERAL GEOLOGY.

CHARACTER OF THE ROCKS.

The rocks of the Kantishna region range from highly metamorphic mica schists and gneisses, through less altered but deformed sediments of Paleozoic age, to the slightly indurated Tertiary coal-bearing beds and to the unconsolidated terrace gravels and the deposits of present streams. Interspersed with these materials are igneous rocks of various ages and of all degrees of alteration and metamorphism. Except in the outermost belt of foothills the rocks on the north flank of the Alaska Range are dominantly of sedimentary origin, although, as may be seen from the sketch map (Pl. XV), considerable areas are occupied by intrusive materials and lavas. Hasty reconnaissance trips to the heads of several valleys have shown that sediments predominate to the crest of the range.

The distribution of the rock formations as shown on the map has been determined only by hurried reconnaissance surveys, in which a wide scope of country was visited in a short summer field season. It has therefore been possible to subdivide and outline the several units in only an approximate manner. Time was not available to follow out all the formational boundaries, and when the geologic field work was done no topographic map was available, so that it was necessary later to adjust the geologic boundaries to the finished map in the office. Furthermore, most of the rock formations here described have so far failed to yield fossils in this district, and their age determination is therefore dependent upon their correlation with similar beds in other localities, or upon their relations to other formations whose age has been established. The age to which some of these formations are assigned may therefore be changed in the future, when fossils are discovered or when the stratigraphic succession is more fully worked out. Under these circumstances it is inevitable that the outlines of the formations as shown will be found to be somewhat in error upon critical examination in the field. Nevertheless, the map is believed to represent with a fair degree of accuracy the general outlines of the formations represented, and to furnish at least a guide for the later worker who has time and facilities for more refined mapping.

STRUCTURE.

The prevailing structural trend of the region is east-northeast, parallel to the axis of the Alaska Range, and has been determined by movements similar to those which brought the present range into existence. The uplift of the present mountain mass, however, did not produce all the metamorphism which some of the rocks have undergone, for that uplift took place in post-Mesozoic time, and before it began some of the rocks here represented, notably the Birch Creek schist and the associated gneisses, had been severely metamorphosed by forces applied in the same direction as those that forced up the present mountains. The Alaska Range was therefore formed along a zone of weakness that had previously yielded to stress. In its uplift the beds were both folded and faulted, and both of these processes were operative in developing the main range and the parallel ranges of foothills, with the broad basins between them.

SEDIMENTARY AND METAMORPHIC ROCKS.

Birch Creek schist.—The oldest rock formation that occurs in this area is the Birch Creek schist, which forms an outlying ridge of mountains extending from Nenana River westward to Stony Creek and west of that stream expands to include most of the Kantishna Hills. West of the Kantishna district the outline of the schist area is not well known, but to the east it extends beyond Delta River and forms a prominent element of the Alaska Range there. The material of the Birch Creek schist consists for the most part of highly contorted and fissile mica and quartzite schists and phyllites and includes garnetiferous and carbonaceous schists. These rocks are believed to represent metamorphosed sediments. In general they may be readily recognized by their thin, flaky cleavage and the abundance of mica, which gives them a greenish to silvery appearance. These rocks are of especial economic importance, for they are in places cut by gold, silver, lead, and antimony bearing quartz veins, and all the workable gold placer gravels so far found have been derived from this schist series.

The age of these rocks is uncertain. From their general appearance and character they have been correlated with the Birch Creek schist of the Yukon-Tanana area, which is believed to be pre-Ordovician.

Tatina group.—The Birch Creek rocks are bordered on the south by a narrow belt of the Tonzona group, south of which, in another narrow belt parallel to the schist, is a series of beds composed predominantly of black slates and argillites, massive graywackes, and some interbedded limestone and chert, all more or less intricately folded and metamorphosed. Brooks classified these rocks with his Tatina group, which he regards as partly Ordovician and possibly in part Silurian. No fossils were found in these rocks between Nenana River and Muldrow Glacier, and no positive additional evidence of their age was procured. From purely stratigraphic grounds, however, there seems to be a possibility that the beds in this area are younger than the Tonzona group. Their position with relation to the Tonzona is what would be expected if they overlay it, and they are directly overlain by the Cantwell formation, of Mesozoic (Tertiary) age. Faulting has been so severe in this region, however, that the normal relations are difficult to ascertain, and these beds are therefore left in the position in the stratigraphic column where they were placed by Brooks.

Totatlanika schist.—A series of quartz-feldspar schists and gneisses younger than the Tatina group form the northernmost range of foothills and extend from a point east of Nenana River westward across the Toklat basin and include the northeast end of the Kantishna Hills, in the vicinity of Chitsia Mountain. These rocks, which have been called the Totatlanika schist, are characterized by the presence of porphyritic schist or augen gneiss, containing phenocrysts of feldspar and quartz and believed to have been formed by the metamorphism of rhyolite or rhyolite porphyry. Associated with the porphyritic schist are finer-grained schists and some carbonaceous slaty schists and in the vicinity of Chitsia Mountain some sandy limestones that are of sedimentary origin. Time was not available for separating the igneous from the sedimentary material in the outer range of foothills, and they have been outlined together on the map with a single pattern. The whole series has been severely metamorphosed and plicated. As no fossils were found in this area there is no definite evidence of the age of these rocks. East of Nenana River they overlie the Birch Creek schist, of pre-Ordovician age. Brooks[1] has correlated the sedimentary phases with his Tonzona group, which he regards as of Devonian or Silurian age.

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[1] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 75, 1911.

Tonzona group.—Along the south border of the Birch Creek schist, between Teklanika River and Stony Fork of Toklat River, there is a narrow belt of black slates and argillites, with some phyllites and schists, that lie upon the Birch Creek schist. In many ways these rocks resemble some of the sedimentary materials included with the Totatlanika schist, but they are comparatively free from material of igneous origin. Brooks[1] has included these rocks with his Tonzona group, which on the basis of its stratigraphic relations he considers to be of Devonian or Silurian age. As no further definite evidence on their age was obtained they are therefore here classified as Devonian or Silurian.

Cantwell formation.—Associated with the beds of the Tatina group and overlying them unconformably is a thick series of sediments, the Cantwell formation, composed of conglomerate, coarse sandstone, and shale. These beds have a thickness of several thousand feet and form a prominent element of the north flank of the Alaska Range. From plant remains found in them and by correlation with other plant-bearing beds east of Nenana River these sediments are classified as of Kenai or early Tertiary (Eocene) age. The beds are generally uptilted, folded, and faulted and locally are cut by intrusive rocks and interbedded with lava flows.

Coal-bearing Tertiary beds.—The Cantwell beds are succeeded by the coal-bearing Tertiary deposits that are so abundantly represented just east of this area, in the Nenana coal field. These beds are generally little consolidated and consist of sands and clays, with lignite interbedded locally. They occupy small areas in the valleys of the higher mountains and larger areas in the open basins between the foothill ranges. In the basin of Teklanika River considerable areas are occupied by the coal-bearing sediments, although the surface exposures are small because of a widespread covering of younger gravels. There can be no doubt that in that basin, at least, there is a large amount of workable lignite, and scattered outcrops of the same formation occur as far westward as the Kantishna mining district, indicating that there may be large bodies of coal that are for the most part concealed by the gravel covering.

The age of the coal-bearing beds is not positively known, for the fossil evidence seems to disagree to some extent with the stratigraphic evidence. Heretofore the coal-bearing materials of the Nenana coal field have been considered to be, at least in part, of Eocene age. Fossil plants collected from the Cantwell formation east of Nenana River by Moffit[2] have been definitely determined as

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[1] Brooks, A. H., op. cit., p. 76.

[2] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 48–49, 1915.

Eocene. Collections made from this same formation by Brooks[1] in the Toklat basin and by the writer in the Teklanika basin have also been determined to be Eocene. The stratigraphic evidence, however, seems to show rather conclusively that the Cantwell beds are considerably older than some of the coal-bearing beds. In the absence of definite paleontologic evidence the coal-bearing materials are here assigned to the Tertiary but are believed to be younger than the Cantwell.

Nenana gravel.—In the basins of Nenana and Teklanika rivers and of East Fork of Toklat River there are certain thick gravel deposits, known as the Nenana gravel, that overlie the Tertiary coal-bearing sediments and have been faulted and tilted with them. These gravels reach a maximum thickness of at least a thousand feet, are deeply oxidized, and in general are conformable with the underlying coal-bearing sediments. They are believed to be of Tertiary age.

Unconsolidated deposits.—Among the unconsolidated and undeformed deposits of the region are the glacial moraine deposits, the bench and terrace gravels, which are in part composed of glacial outwash material, and the deposits of the present stream flats. The only morainal materials in this area were left by the ice during the last stage of glaciation and are confined to the mountainous portions of the area. At a few places distinguishable terminal moraines are present, but in general the glacial materials form only a thin covering over the mountain flanks. The bench and terrace gravels are of wide extent in the lowlands between the foothill ranges and in the Tanana lowland. They consist of materials derived from a number of sources—outwash materials from the ancient glaciers, reworked gravels from the Tertiary formations, and deposits laid down by the present streams before the flood plains now occupied were established. The gravels included in this classification are all related to the present topography of the region and retain the attitude in which they were laid down. They are of Pleistocene and Recent age.

The gravels along the flood plains of the present streams, although composed in part of outwash from the existing glaciers, represent the last stage of geologic activity and, with the accumulations of rock débris on the mountain slopes and of soils and vegetable humus on the gentler slopes, are the product of present-day geologic process.

IGNEOUS ROCKS.

Igneous rocks of various types and of different ages are present throughout the Kantishna region. They include certain greenstones that are included in and are deformed with the Birch Creek schist; the Totatlanika gneisses are in large part of igneous origin; beds of greenstone underlie the Cantwell in places; and both the Cantwell and the Tertiary coal-bearing beds are cut by intrusives and contain interbedded lava flows. Dike rocks of granitic material cut the schists in the Kantishna Hills, and large masses of granitic rock are known to be present in the Alaska Range north of the area here described.

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[1] Brooks, A. H., op. cit., p. 82.

ECONOMIC GEOLOGY.

HISTORY OF MINING.

The basin of Tanana River assumed importance as a placer-mining region on the discovery of rich placer gravels in the Fairbanks district. As a consequence of that discovery a great stampede to the Tanana Valley took place in 1903 and 1904. Most of the gold seekers went to the new town of Fairbanks or to the creeks in that vicinity, but a few penetrated to the north slope of the Alaska Range and carried on the search for gold there. The discovery of gold in the Kantishna district was an indirect result of the Fairbanks rush. In 1904 Joe Dalton and his partner Reagan prospected in the basin of Toklat River and after having found encouraging amounts of gold returned to Fairbanks that fall. The next spring Dalton and another partner named Stiles returned to the Toklat and prospected on Crooked Creek, a tributary heading in the Kantishna Hills 16 miles northwest of Mount Chitsia. In the summer of 1905 two other prospectors, Joe Quigley and his partner Jack Horn, had been told by some trappers that there was gold in Glacier Creek, and they came in to investigate. They found gold in paying quantities, staked the creek, and in June of that year carried the news of their discovery to Fairbanks, and so started the Kantishna stampede. The stampeders began to arrive at Glacier Creek about July 15, 1905. Meanwhile Dalton and Stiles, who had heard nothing of the Quigley-Horn discovery, had followed the southeast side of the Kantishna Hills and arrived at Friday Creek. They found gold there and on July 12 staked that stream. On July 20 they staked Discovery claim on Eureka Creek, but thinking themselves entirely alone in the country they staked only the one claim, having determined to prospect the upper portion of the stream. They went up Eureka Creek and on their way back met a man named Cook, who had come in with the stampede and had made his way up Moose Creek to the mouth of Eureka Creek. Cook said he had staked claims Nos. 1 to 4 on Eureka, so Dalton and Stiles returned and staked the rest of the creek above claim No. 4.

During the later part of the summer and the fall of 1905 the Kantishna district was the scene of great excitement. Several thousand persons arrived, most of them by boat up Kantishna River and its tributaries, Bearpaw and McKinley rivers. during the season of open water, and by dog sled later in the fall after snow had fallen. Practically every creek that heads in the Kantishna Hills was staked from end to end, and the benches and intervening ridges were not ignored. Within a few weeks a number of towns were established, the largest of which were Glacier, on Bearpaw River at the mouth of Glacier Creek; Diamond, at the mouth of Moose Creek; and Roosevelt and Square Deal, on McKinley River. At each of these places dozens of log cabins, stores, hotels, and saloons were erected, and between them and the creeks a constant stream of gold seekers traveled back and forth. By midwinter, however, it became generally known that rich shallow diggings, the eternal hope of the prospector, were restricted to a few short creeks, and the exodus began. In the summer of 1906 vigorous mining was done on the richest ground, but by fall the population had dwindled to about 50, those who remained being the few who had obtained paying claims or who were convinced that thorough prospecting held out sufficient promise of new discoveries.

The winter of 1906 saw the nearly complete desertion of the towns of Roosevelt, Square Deal, and Diamond. Glacier, being nearest to the creeks, was and still is used as winter quarters by a number of miners who prefer to spend the cold months in the shelter of the timber and near their fuel supply rather than haul wood to their summer camps.

Since 1906 the population of the Kantishna district has remained nearly stationary at 30 to 50 persons. In 1916 there were 35 persons in the district, and of this number over half were men who had staked claims during the first stampede and had worked them more or less continuously since that time. It was placer gold that first attracted attention to this camp, and the only gold so far produced has come from the placer gravels. In recent years, however, considerable attention has been given to prospecting for lode deposits. Veins carrying gold and silver and the sulphides of lead, zinc, and antimony occur in the district, and a large number of lode claims are now held. No lode mine has yet been developed to a producing basis, but there is good reason to believe that eventually the lodes may outstrip the placers in the value of their metal yield.

GOLD PLACERS.

GENERAL FEATURES.

The productive gold placer deposits of the Kantishna district all occur in the basins of the streams that head in the Kantishna Hills and radiate in all directions from the higher peaks. The so-called Kantishna Hills are actually rugged mountains of considerable size and are known as hills only because of their nearness to the towering peaks of the Alaska Range. As each stream basin is separated by high dividing ridges from its neighbors and direct travel from one basin to another is difficult, the routes generally used follow the bases of the higher mountains, and the placer workings are therefore much farther apart, by trail, than their close spacing on the map would indicate. These conditions have resulted in the development of a number of small and rather isolated mining camps between which there is little travel during the busy summer season. Paying deposits of gold placer gravel were found in 1905 and 1906 on all the streams that are now productive except Little Moose Creek, and although considerable prospecting has been done in the last 10 years only a small amount of workable ground has been discovered since the early years of this camp. This may be due in part to the fact that only the richest claims can now be worked at a profit, but most of the men in the district own ground from which they are confident they can make a living, and the summer is employed in mining the proved ground rather than in prospecting in areas of less certain value.

The streams that have added to the gold production of the district are Moose Creek and its tributaries, Glen, Eureka, Friday, and Eldorado creeks; Glacier and Caribou creeks, tributaries of Bearpaw River; and Little Moose Creek. which flows into Clearwater Fork of Toklat River.

MINING CONDITIONS.

All the placer mining that has so far been done in the Kantishna district has been open-cut mining, the method commonly employed being to groundsluice off the upper part of the gravel within a foot or so of bedrock and shovel the remaining gravel and the necessary amount of bedrock into the sluice boxes by hand. Most of the miners plan to complete the season's groundsluicing early in the spring, during the period of greatest stream flow, but a few have built automatic dams and are thus enabled, by alternately storing the water and then releasing a large volume for a short period, to groundsluice even in times of low water. The whole operation of open-cut placer mining is, however, definitely limited to the period of stream flow. In this district nearly all the placer mines lie above timber line, at altitudes of 1,600 to 3,000 feet. At such altitudes the streams do not commonly run free from ice until sometime in May and freeze again late in September, and the mining season is therefore limited to about four months. Late in the summer, too, some of the smaller streams diminish so much in volume that sufficient water for sluicing is lacking, and the mining season is thus restricted still further. The experienced miners in this camp count upon a working season of 100 to 120 days.

Most of the gravel deposits along the streams are in thawed ground, and the miners in general encounter little difficulty with ground frost. Certain of the elevated benches, however, in which gold in commercial quantities is known to occur, are permanently frozen, and before the gravels can be sluiced they must be thawed, either by the use of steam or by stripping away the insulating cover of surface vegetation and muck to make the gravels accessible to the warm air and the direct rays of the sun.

The remoteness of this mining camp from established lines of transportation has resulted in greatly increasing mining costs. Little labor is employed at stipulated wages, for most of the claims are worked by the owners or on a royalty basis, but for such labor as is employed the prevailing wages are $6 a day and board for a 10-hour day, or $1 an hour without board. Even at such wages, however, it is difficult to obtain labor, for there is no means of ready communication with any settlement, and the men in the camp at any one time include only those who remained from the preceding year and those who come in over the ice in the winter or by boat in the spring.

The necessary supplies and mining equipment for the season's operations are brought to the district by the operators, either by launch to Diamond and thence by sled to the mines or by sled all the way from Fairbanks during the winter. The quantity and assortment of his supplies must therefore be determined by each miner several months in advance of the working season, and he has to invest a considerable amount of capital for an unusually long period. No store is maintained in the district, and whatever supplies a man unexpectedly finds he needs during the summer he must procure from his neighbors or do without. As a result of the difficulty and expense of landing freight at the mines and the long time involved in procuring equipment, only the most primitive methods of mining have been employed. All the gold so far recovered has been taken out by pick and shovel.

With the exception of the mining claims on Moose Creek, all the placer ground mined in 1916 lies above timber line, and wood for fuel as well as lumber for mining purposes must be brought from a distance.

This distance varies on the different creeks. On Glen Creek timber grows within 1 to 3 miles of the mines. Eureka and Friday creeks are devoid of timber, which must be obtained from the basin of Moose Creek, 1 to 5 miles from the workings. On Glacier Creek no timber is obtainable for a distance of 8 miles from the head of the creek, and the length of haul for the uppermost placer claims now worked is about 6 miles. The mine on Caribou Creek is 5 miles from timber line, and that on Little Moose Creek is perhaps 2 miles from the nearest trees that are large enough to supply sluice-box lumber. In the early days of the camp sawmills were operated to furnish lumber, but these were soon dismantled, and now all needed lumber must be cut by whipsaw.

ORIGIN OF GOLD PLACERS.

As is shown in Plate XV, the entire Kantishna mining district lies in an area in which the underlying rock is the Birch Creek schist, cut by relatively small bodies of intrusive rocks. The intrusive rocks are of a wide range in age. Some appear to have suffered as severe metamorphism as the schists that inclose them. Other bodies of intrusive material are somewhat metamorphosed, but less so than the schists and were intruded after metamorphism was started, but before it was completed. Still other intrusive bodies are not at all folded and were injected after the schists had reached their present condition. Among these youngest intrusives are some dikes and stocks of granite porphyry and quartz porphyry that may be genetically related to the mineralized quartz veins. The schists are in places highly siliceous and include beds of quartzite schist. Throughout the area in which it occurs the Birch Creek schist contains numerous quartz veins and veinlets, distributed through the entire rock mass. Gash veinlets and lenticular bodies of quartz, lying parallel to the schistosity, are particularly abundant, but as a rule quartz veins of this character are not regular or continuous for long distances but pinch and swell abruptly. Tiny reticulating veinlets of quartz cutting the schist in all directions are also common. Many quartz veins of this type have been twisted and metamorphosed with the inclosing schist. In the area of the Kantishna Hills, especially along the main divide and from the heads of Caribou and Myrtle creeks westward to the basin of Moose Creek, there are many large quartz veins that cut across the cleavage planes of the schist, stand at steep angles, and maintain their strike, dip, and thickness for considerable distances along the outcrops. These veins are, in general, younger than the gash veins that follow the schistosity and are true veins, of more recent age than the last period of vigorous metamorphism. Several quartz veins of this type have been found to contain visible free gold in encouraging quantities, and mortar tests show that native gold is rather widely distributed in these veins. Furthermore, the largest and most continuous gold-bearing quartz veins that have been found are in the basins of those streams whose placers have yielded the most gold. This seems to be conclusive proof that the gold of the placer gravels was derived, at least in large part, by the erosion of the larger quartz veins that cut the schists. The gash veins and veinlets of quartz in the schists may also have added their contribution of gold to the stream placers, and the presence of placer gold in greater or less amount in almost all the streams that flow through the schists indicates that some of these veins are gold bearing, but the richest placer gravels have been found in basins in which the larger veins occur.

The local origin of the placer gold is also confirmed by the appearance of the gold itself. In Friday and Eureka creeks, immediately below the outcrops of some large quartz veins, the placer gold is surprisingly rough and angular. Many nuggets show the unworn crystalline form that the gold had as it lay within the vein quartz, and few nuggets in any clean-up show any appreciable effects of attrition. To anyone familiar with the usual appearance of placer gold it is immediately evident that this gold is recovered at no great distance from the outcrop of the vein in which it originated. Downstream, away from the outcrops of gold-bearing quartz, the placer gold becomes finer and more smoothly worn, as would be expected if the gold has been derived from the quartz veins and has been transported to increasingly greater distances from its bedrock source.

The influence of glaciation upon the distribution of gold placer deposits in the Kantishna region has differed in the different stream basins, and although the glaciers have doubtless played their part in the erosional history of the district, the ice was much less abundant here than in the higher mountains of the Alaska Range. It has now been established that there have been at least two epochs of glaciation on the north side of the Alaska Range, one much earlier than the other, the evidence of which is better preserved. It is difficult in certain places to determine the limits reached by the separate ice sheets, for evidences of the earlier glaciation can easily be mistaken for those of the later, and a proper discrimination of the data can be made only after more detailed field work has been done. Nevertheless, it is certain that at one time Muldrow Glacier was much larger than it is now and that it overflowed the northern border of its present basin and spread northward across the upper basin of Moose Creek, to lie against the south flank of the Kantishna Hills. One tongue from this ice lobe flowed northward into Clearwater Fork of Toklat River, another down Moose Creek past Eureka and Eldorado creeks, and still another westward along the present course of McKinley River. The highest ridges of the Kantishna Hills were never overridden by ice, but the higher and more favorably situated valleys in them supported small ice tongues, which extended radially from the crest in all directions but which never attained sufficient length to reach beyond the confines of the narrow valleys. Of the gold-producing streams Glen, Glacier, and Caribou creeks were glaciated in their upper ends, but the Eureka, Friday, and Eldorado Creek basins were not high enough ever to have originated glaciers. Abundant erratic boulders occur throughout the basin of Moose Creek above Eureka and in the valleys of Eldorado and Eureka creeks nearly to their heads. These were not found in direct association with morainal deposits, but they indicate that at some time the basin of Moose Creek was filled with ice, which lay high against the south flank of the Kantishna Hills and which left the boulders that now appear. The peculiar courses followed by lower Spruce and Glen creeks also indicate changes of drainage due to glacial occupancy.

To just what extent the gold-producing streams were once occupied by glaciers and their preglacial placer deposits removed by ice erosion has not been definitely determined, for the glacial evidences are inconspicuous and poorly preserved. It can be stated, however, that in those portions that were glaciated the erosion of the ice was sufficiently severe to disturb or remove the greater part of the preexisting gold placer deposits, so that any concentrated deposits of gold that are now present are due to the erosion of streams since the ice retreated. Below the edges of the glaciers stream erosion was retarded during the ice advance, for the waters were burdened with an unusually large supply of rock waste, and this they deposited as outwash gravels beyond the ice edge. The streams assorted the materials of the outwash gravels to some extent, but much less than is common in normal, lightly loaded streams.

With the final shrinkage and disappearance of the glaciers from this district the streams commenced their task of readjusting their valleys to conditions of normal erosion. Less heavily loaded than when they were receiving glacial waters, they began to intrench themselves in the deposits of outwash gravels, which now appear as high benches or terraces along the lower streams, especially those on the north side of the Kantishna Hills. In cutting down through these gravels the streams in places occupied somewhat different courses from those along which they had formerly flowed, and canyons show the position of obstructions encountered in the downward cutting.

Bench or terrace gravels along Moose, Glacier, and Caribou creeks have been shown to contain encouraging amounts of placer gold, and in one or two places the gold content has been sufficient to warrant mining. During intrenchment of the streams through these gravels the gold they contained, as well as that supplied by the erosion of gold-bearing quartz veins, was deposited in the stream beds, resulting in the present workable placers.

WHITE GRAVELS.

Among the miners in this district a misconception prevails regarding certain white quartz gravels that occur along the north flank of the Kantishna Hills. These gravels have been noted especially in the valley of Glacier Creek, near the point where the schist bedrock plunges downward to the northwest and disappears beneath the deposits of unconsolidated materials. They are nowhere conspicuous on the surface but have been found in place only in prospect holes, although gravels of this type have been noted in the stream deposits of Glacier Creek below the point where the schist bedrock disappears. The most complete information concerning the white gravels was procured from a prospect shaft sunk on the bench west of Glacier Creek, opposite the upper end of claim No. 13. This shaft, after penetrating a few feet of the ordinary bench gravels, encountered a body of white rounded quartz gravel that continued without interruption to a depth of 114 feet, at which the sinking was discontinued without reaching bedrock. Most of the material on the dump is vein quartz, distinctly rounded and waterworn, ranging in size from fine sand to pebbles 6 inches in diameter. The resemblance of this material to the "white channel" gravels of the Klondike was at once apparent to the prospectors, who entertained high hopes of finding rich gold placer deposits in it, but although some fine gold was panned from the material excavated, no paying concentration of gold was found. A study of the geologic relations on Glacier Creek indicates that the white gravels there constitute the base of the Tertiary coal-bearing formation that is so fully developed to the east near Nenana River. In that area the base of the Tertiary beds, which lie upon the Birch Creek schist, is commonly made up of a nearly pure deposit of white quartz pebbles and sand. This relation continues westward across the basin of Teklanika River, and, no doubt, the Glacier Creek white gravels are of similar origin. The gravels are believed to represent the detritus from an old land mass which had been deeply weathered and from which the more easily decomposed materials had been removed, leaving abundant residual quartz scattered over its surface. A period of more active stream erosion followed, and this quartz was removed, rounded by the streams, and deposited as a widespread blanket over the lowlands. It was brought to the lowlands by many small streams rather than by a single large one, and in the lowlands that were aggraded by the gravel deposit there was little tendency to concentrate any gold that may have been present in the quartz. Throughout the area in which they have been studied these white quartz gravels contain a little gold, but nowhere have concentrations sufficiently rich for placer mining been found. At the Glacier Creek locality the exposures are not good, but so far as known the white gravels are not overlain directly by the coal-bearing Tertiary beds, but by a thick deposit of tilted oxidized gravels, which in the Nenana district succeed the coal-bearing beds. This means either that the coal-bearing beds were removed by erosion from over the white quartz gravels before the later yellowish gravels were laid down, or that in this place coal-bearing beds were never developed and the oxidized gravels were laid down directly upon the white gravels. The white-gravel deposit on Glacier Creek therefore differs in mode of origin from the Klondike "white channel," and being probably of early Tertiary age it is apparently much older than the gravels of the Klondike.

SOIL FLOWS.

A factor that has exercised a notable influence upon the gold placer deposits in many valleys is the large volume in which detrital material from the valley walls moves down the slopes and out upon the stream gravel deposits and the rapidity with which this movement takes place. In this latitude both the annual and the daily range of temperature are great, and consequently rocks disintegrate rapidly, especially rocks so fissile as the schists that form the bedrock within the Kantishna district. The disintegration is probably not so rapid during the months of constant low temperatures as in the spring and fall when the temperature crosses the freezing point twice daily. The mantle of rock disintegration products soon becomes frozen, for in the higher parts of this area the ground is permanently frozen beneath a thin covering of vegetation and soil. The disintegrated rock is soon covered by mosses, heather, and other plants that form a tough mat. Erosion of this detrital material by streams is slow, for in spite of steep slopes the vegetal covering is tenacious, and the ground frost greatly retards stream cutting. As a result of these factors the surface mantle of detritus, composed of the so-called muck of decomposing plant remains, soil, and rock fragments, both fine and coarse, accumulates to a thickness of several feet, even on steep slopes, and is almost immune to erosion by surface streams. The material has, however, a decided tendency to creep bodily down the slopes. During the warm summer season the surface portion becomes thawed, and as it contains large amounts of water it tends to move downward by gravity. In most places this movement is slow, for the feltlike mat of vegetation retards it, and the surface features developed have the appearance of broad, flat lobes, such as would be formed by the flow of a very viscous mass on a steep slope. In places, however, the cover of vegetation becomes torn, and the semifluid mass of muck, soil, and rock fragments flows rapidly down the slope to the valley. In some recent flows of this kind that were examined the thickness of the surface material that flowed out was determined by the depth to which thawing had taken place before the thawed mass broke its surface covering of vegetation. Although several such fresh soil flows were seen and the old, healed scars of great numbers of similar flows were recognized, the prevailing movement of detritus is by slow, scarcely perceptible creep.

The economic bearing of these soil movements upon the placer deposits of the district is to be observed in many of the narrow valleys where mining is in progress. In the headward portions of the streams the valleys are narrowly V shaped, and each creek has a flood plain a little wider than the stream itself. Mining operations have disclosed the fact that in many places flows of detritus containing muck, soil, and coarse talus have moved down the valley sides and out upon the stream gravels and have buried the pay streak many feet deep. In such places the richness of the gold concentration must determine whether or not the excavation of the "slide" from the valley side is justified. Such "slides" occur on Eureka, Friday, Glacier, and Little Moose creeks. On Little Moose Creek a large mass of material, rendered unstable by the excavation of creek gravels at its base, flowed suddenly into the placer workings, covered the sluice boxes, and filled the cut with mud. In other places the unusual depth to bedrock encountered by prospectors is no doubt due to the influx of surface material from the valley sides, and it is likely that many claims containing concentrated deposits of placer gold now unavailable for mining would yield a profit if the overburden due to soil flowage were absent.

MINES AND PROSPECTS.

During August, 1916, all the mines and prospects on which work was being done were visited, and the following pages contain brief descriptions of the general conditions prevailing at that time. The position of the mines and prospects is shown in Plate XV, and in the discussion they are grouped under the stream valleys in which they occur and are described in order from the uppermost claim downstream.

GLEN CREEK.

Claims Nos. 1 and 2 on right fork.

Some mining was done by one man on claim No. 1, the lowest claim on the right fork of Glen Creek. A large part of the season was spent in building an automatic dam, but during the period of low water the dam leaked so badly that it would not fill up and flush, and only 36 linear feet of bedrock below the dam had been cleaned. In previous years considerable work was done on claim No. 2, by the ordinary method of groundsluicing and shoveling in. Boxes 12 inches wide, set on a grade of 10 to 12 inches to the box length, are used. The bedrock is composed of quartzite and micaceous schist, and boulders are large and abundant. On claim No. 2 the depth to bedrock averages about 6 feet, but a short distance below the dam, on claim No. 1, the bedrock surface plunges suddenly downward, and a shaft 34 feet deep, sunk near the forks, failed to reach it.

The gold is bright, coarse, and rough, and many nuggets weighing from 1 to 7 ounces each have been recovered. The sluice-box concentrates contained abundant black sand, garnets, galena, and iron pyrite, indicating that the gold has been derived from sulphide-bearing quartz veins. Such veins crop out at the head of this basin and doubtless have furnished gold to the placer gravels.

Claim No. 9.

In July, 1916, three men were mining on claim No. 9. An automatic dam was in operation, and a cut nearly 500 feet long had been groundsluiced. Bedrock had been cleaned for a distance of about 150 feet in this cut. The gravels range from 5 to 8 feet in depth and contain numerous boulders and slabs of schist, some of which are too large for one man to handle. The stream flow was sufficient for the mining operations, and 12-inch sluice boxes, set on a grade of 7½ inches to the box length, were used. The gold is coarse and rather rough and assays from $15 to $15.80 an ounce. Many of the nuggets are discolored, but the fine gold is bright and yellow. Many nuggets ranging from 1 to 3½ ounces have been found. The sluice-box concentrates contain numerous pieces of galena and black-coated pebbles and small boulders of the manganese metasilicate rhodonite. It is reported that about half of claim No. 9 has been mined.

Claim No. 7.

No one was present on claim No. 7 at the time it was visited, but it is reported that one man was mining there in 1916. In July some groundsluicing had been done, but little gravel had been shoveled into the sluice boxes. The mining conditions on this ground, a large part of which is said to be worked out, are much the same as on claim No. 9.

Other claims on Glen Creek.

Some mining has been done on Glen Creek each year since 1906, and a number of claims have contributed to the gold production. Claim No. 6, below which little more than prospecting has been done, has been partly mined, and No. 7 is largely worked out. Parts of claims No. 8 and No. 8 fraction have been worked, and claim No. 9 is about half exhausted. No extensive mining has been done above claim No. 9 on the main creek, but on the right fork parts of claims Nos. 1 and 2 have been mined.

EUREKA CREEK.

Claim No. 13.

The uppermost claim on which mining has been done on Eureka Creek is claim No. 13, on which one man has been working since 1906. Sluicing operations were begun on the lower end of the claim and have now been carried upstream for a total distance of about 1,000 feet. The bedrock of this creek, composed of Birch Creek schist, varies in hardness from place to place, hard quartzitic phases alternating with softer mica schist. The foliation of the schist here strikes roughly parallel with the direction of the valley of Eureka Creek and dips at high angles. At the time of visit ground to the depth of 11 feet was being mined, for the pay streak was buried by the movement of materials from the north valley wall. An automatic dam was used for groundsluicing, but during the season of 1916 the water supply was insufficient for satisfactory mining. Sluice boxes 12 inches wide, with pole riffles, were set on a 9-inch grade, and below these were set boxes with false bottoms on a grade of 5 inches to the box length. Boulders and slabs of rock, some of them 4 feet in diameter, are numerous and add to the difficulties of mining. Practically all the gold occurs on bedrock, and much of it is discolored by stains from the decayed rock. The gold is said to assay $16 an ounce, and, although coarse, is finer and smoother than that taken from the claims below. The largest nugget taken from this ground weighed 2¼ ounces.

Eureka group.

The lowest ground on which active mining was done on Eureka Creek in 1916 is the Eureka group, consisting of claims Nos. 5 to 12 above Discovery, which is at the mouth of the creek. On this group a strip about one cut wide (about 20 feet), and including the bed of the stream, has been mined from the lower end of claim No. 5 up to and including a part of claim No. 9, and mining has been carried on here each year since 1905. Until recently all mining had been done by pick and shovel, and only the richest gravels—those in the creek bed—could be handled at a profit. In 1916 an automatic dam was built on the upper end of the group, and through its use mining costs have been so reduced that a much wider strip of gravels can be profitably exploited. It is reported that the cost of mining has been reduced from $45 a box length (168 square feet) under the old method of groundsluicing and shoveling in to $20 a box length by the automatic-dam method. The gravels are sluiced off until the high points of bedrock are exposed, and only about 6 inches of gravel is shoveled by hand. The owner reports that tests show that little gold is lost by this method. The gravels have averaged about 7 feet in thickness in the stream bed and 8 to 9 feet on the low benches. Coarse boulders are not unusually abundant, and, although a few have to be broken by explosives, most of them can be thrown aside by hand. On the lower end of claim No. 9 the creek flat widens to about 40 feet, and the whole flat was being worked at the time of visit (August, 1916). The owner plans to continue mining by the present automatic-dam method to the head of the group of claims and then work the ground on the lower claims on either side of the creek channel—ground that by the old method would not pay. The bedrock is the Birch Creek schist, the character of which changes from place to place. In cleaning bedrock it is necessary to remove only a part of the schist where the rock is comparatively soft, but in the harder phases the gold has penetrated more deeply into the cracks, and 2 feet of bedrock must be removed to recover all the gold. The gold is bright yellow, except those pieces which have lain on decayed and rusty bedrock and are discolored. It assays from $15 to $15.20 an ounce. A large part of the gold recovered is in rough, angular pieces that show little or no evidence of stream abrasion. Many pieces show unworn crystal surfaces and are certainly derived from gold-bearing lodes near by. In many nuggets quartz is intermingled with the gold, and the sluice-box concentrates contain abundant galena, giving additional evidence that the gold was concentrated from the quartz veins that crop out on the ridges that border this stream basin. Stibnite and black sand are also caught on the riffles. The placer gold from Eureka Creek is also unusually coarse. Half of that recovered is said to occur in pieces having a value of 5 cents or over, and much is still coarser. One nugget from claim No. 9 had a value of $100, and another taken from Discovery claim in 1906 was worth $900.

The water supply on Eureka Creek is ordinarily abundant for sluicing operations throughout the open season. Four boxes 11 by 13 inches in cross section set on a grade of 9 inches to the box length, two equipped with pole riffles and two with Hungarian riffles, are used, and the lower boxes, with false bottoms, are set on a grade of 5 inches to the box length. Two or three men were employed throughout the season.

On claim No. 12 of the Eureka group one man operating on a lease was mining for part of the season. The conditions encountered were much the same as on claim No. 9, the gravels being from 7 to 9 feet in thickness.

Other mining.

In the earlier years of mining activity in this district placer mining was done on all the claims from the mouth of Eureka Creek up to claim No. 5, and the main stream bed has now been mined up to and including part of claim No. 9. Throughout the length of these nine claims, however, there are locally patches of gravel on each side of the creek which are known to contain considerable placer gold but which were left by the miners in their haste to work the richest and most easily accessible ground. As the richer gravels of the main creek bed become exhausted, the less easily handled "side pay" on these claims will be mined, and by the use of more economical methods, such as automatic-dam sluicing, these neglected areas are likely to yield a satisfactory profit to the miners.

FRIDAY CREEK.

Friday Creek, a small tributary of Moose Creek from the east, joins that stream 1½ miles below the mouth of Eureka Creek. The valley of Friday Creek is only 2 miles long, and the gradient of the stream is steep and its valley narrow. The stream flat is in general not more than 15 or 20 feet wide, and for a considerable part of its length the creek flows in a narrow, canyon-like cut between rock walls, with only narrow and shallow gravels in the stream bed.

Claim No. 2.

One man was mining on the upper end of claim No. 2, the creek bed in the lower part of the claim having already been mined out, although some workable ground is said to remain along the sides of the strip that has been mined. Mining conditions here are much the same as on the other claims on this creek. The stream gravels range in width from 15 to 150 feet, and in places the pay streak runs under slide material from the valley sides. Locally this slide material is frozen. Boulders and slabs of the schist bedrock, too large to pass through the sluice boxes, are abundant, but none are too large for one man to handle. The gold is rough and coarse, nuggets of a maximum value of $50 having been found. The gold taken from the surface of the bedrock is usually discolored and rusty, but the gold from the gravels is bright.

Claim No. 1.

Claim No. 1 has been mined since 1914 by the owner, who also holds a 300-foot fractional claim adjoining the upper end of claim No. 1. The ordinary method of groundsluicing and shoveling in is employed, and a hose, with water under pressure, is used to clean the bedrock. Sluice boxes set on grades ranging from 8 to 16 inches to the box length are lined with pole and Hungarian riffles. The schist bedrock ranges in character from hard, dense rock to soft, soapy, decayed material, and experience has shown that the hard bedrock has retained most of the gold and the softer phases are, in general, only slightly productive. The creek-bed gravels range in depth from 3 to 4 feet, but in places the pay streak is covered with slide material from the valley sides, and an overburden 10 to 15 feet thick must be removed to reach the bedrock. The gold is coarse and very rough, having come from the eroded portions of quartz veins that crop out on the mountains near by. The largest nugget taken from this claim weighed 6½ ounces, and many pieces weighing over an ounce have been found. Black sand and galena are the most abundant heavy concentrates in the sluice boxes. Most of this claim has now been mined, but the fractional claim immediately above it is still unworked.

Discovery claim.

The lowest claim on which active mining has been done on Friday Creek is Discovery claim, the second claim above the mouth of the stream. Two men have been mining here each summer since 1908, and the stream channel has been about mined out, the only unworked ground being a side cut near the upper end of the claim. On the upper portion of this ground the bedrock consists of schist, the foliation of which strikes roughly parallel with the trend of the valley and dips at high angles. About 300 feet above the lower end of the claim the bedrock floor steepens and disappears beneath a gravel filling so thick that so far prospect holes have failed to penetrate it. Mining has been done only by pick and shovel, the pay gravels averaging between 3 and 4 feet in thickness. Two sluice boxes lined with pole riffles and one with Hungarian riffles, set on a grade of 9 inches to the box length, are used, and below them boxes with false bottoms are set on a 5-inch grade. The gold is bright, coarse, and extremely rough. Many nuggets show the crystalline character of the gold as it came from the vein quartz, and quartz is common in the nuggets. Few pieces show conspicuously the effects of stream abrasion, and it is certain that much of the placer gold had its bedrock origin in the gold-bearing quartz veins that crop out in this basin, particularly on the ridge between Friday and Eureka creeks. The gold is said to assay $14.82 an ounce and is associated in the sluice boxes with abundant galena and black sand.

ELDORADO CREEK.

At several places on Eldorado Creek, especially at a point about 2 miles above the mouth of the stream, there is evidence that some placer mining has been done, though no one was working there at the time of visit. The bedrock at the place mentioned is a black slaty phase of the schist that strikes in general northeast and dips steeply to the southeast. The gravels apparently range from 2 to 4 feet in thickness. It is reported that the gold is too unevenly distributed for successful mining. The gold is said to be bright, well worn, and finer than that on Friday and Eureka creeks, and to assay about $16.25 an ounce.

MOOSE CREEK.

The valley of Moose Creek, beginning at the mouth of Eldorado Creek and extending 3½ miles downstream, is held as a block of claims by the owners, who have mined on this ground each year since 1906. Discovery claim lies at the upper end of this property, and it is evident that most of the placer gold in this part of the valley of Moose Creek has been supplied by the tributaries Eureka, Eldorado, and Friday creeks, for no workable ground has been found in the valley above the point which the gravels from Eureka and Eldorado creeks have reached. Only mining on a small scale, by pick and shovel, has been done in Moose Creek valley. Moose Creek is a large clear stream that flows over a gravel flat and is generally bordered by gravel benches, though in places it swings to one side or the other of its valley and cuts against the rock valley walls. About 3 miles below the mouth of Eureka Creek it enters a rock canyon, through which it flows for some distance. Its gradient is so gentle that difficulties are encountered in obtaining water under sufficient head for sluicing and in obtaining a dump for tailings from the sluice boxes.

At the time of visit two men were mining opposite the mouth of Eureka Creek, on a gravel bench whose lower edge stands 10 or 12 feet above the level of Moose Creek. Water was obtained through a ditch that is supplied by Eldorado Creek. Pick and shovel methods were used. Twelve lengths of sluice boxes, 12 by 14 inches in cross section and set on a grade of 5 inches to the box length, were so arranged as to dump directly into Moose Creek. The gravels mined averaged 8 feet in thickness and lay upon a false bedrock composed of blue clay, sand, or semiconsolidated gravel. The gold is distributed throughout the thickness of the gravels, but there is a notable concentration on the false bedrock. Practically no gold has been found within or beneath the material composing the false bedrock, and no one has so far succeeded in sinking a hole through this material to the underlying schist. The gold taken from the gravels is coarse and yellow, but that taken from the surface of the false bedrock is discolored, some of it being nearly black. Although it has probably been derived in large part from the Eureka Creek basin, the gold from Discovery claim averages finer than that found in Eureka Creek, and most of it is in flat, well-worn particles. It is reported that considerable mining has been done at three other localities on this block of claims and that assessment work, including the clearing away of brush and timber, and prospecting have been done each year.

GLACIER CREEK.

Glacier Creek heads against the north side of the Kantishna Hills, flows northwestward through a deep valley eroded in schist for a distance of about 5 miles, and emerges from the mountains, to flow in a northerly direction to its junction with Bearpaw River through a valley intrenched in a broad gravel-covered upland. For the upper 5 miles the stream occupies a valley floored with stream gravels of moderate depth, lying upon schist bedrock. North of the mountains the depth to bedrock increases so as to be below the limit of ordinary open-cut placer-mining operations, except in a few short stretches through which the stream has cut shallow canyons in the schist. Except in these short canyons, the stream in the lower 10 miles of its course flows over a gravel flat that is bordered by high, smooth-topped ridges, in which no hard rocks crop out but which are composed for the most part of rather ancient, tilted gravels—the Nenana gravel.

Placer gold has been found both in the stream gravels and on the benches of Glacier Creek throughout its length, but mining operations have been successfully conducted only in the upper 8 miles of the valley.

Claim No. 20.

The uppermost claim on which mining was done in 1916 is claim No. 20, situated 1½ miles above the point at which Glacier Creek emerges from the mountains. On this claim two men were sluicing gravels that averaged about 5 feet in thickness and lay on schist bedrock. Sluice boxes 12 inches square in cross section, lined with pole and Hungarian riffles and set on a grade of 6 to 8 inches to the box length, were in use. The gold is said to occur both in the stream gravels and on the surface of bedrock. That from the gravels is bright and yellow, but that taken from bedrock is generally stained and discolored. The gold is coarse but is said to be unevenly distributed, rich spots being surrounded by lean areas, in which there is insufficient gold to pay the cost of mining.

Claim No. 18.

One man was mining on claim No. 18 and has worked there each summer since 1908. A splash dam and a bedrock drain had been erected, but a freshet in the spring washed out the dam and filled the drain and made mining difficult. Large boulders are especially abundant on this claim, and the difficulties of mining are increased by the tendency of the pay streak to run beneath the coarse angular talus of the valley sides. The gravels in the stream bed range from 3½ to 9 feet in depth. Black sand and garnets are said to be abundant in the sluice-box concentrates.

Claim No. 14.

Claim No. 14, on Glacier Creek, is the site of the first discovery of placer gold in paying quantities within the Kantishna district, and it has been mined intermittently since 1905. About 900 feet of the creek bed and a portion of the west bench have been worked. One man was mining on the lower end of this ground in 1916. A bedrock drain has been installed, and mining was carried on by the usual method of groundsluicing and shoveling in the gravels and the surface of the bedrock. The schist bedrock ranges from soft, decayed material, that has retained the gold poorly, to hard, firm rock, on which the gold is most abundant. Some gold occurs in the stream gravels, but the richest concentration is on the surface of the bedrock. The gold content varies markedly within short distances, almost barren stretches of gravel being succeeded by other stretches of rich ground. Few large nuggets are found on this claim, the gold occurring for the most part in flat well-worn pieces the size of rice grains.

An irregularly shaped area, measuring in its maximum dimensions 160 by 200 feet, has been mined on the west side of Glacier Creek, on a bench that has a steep face 40 feet high at the creek edge and slopes upward toward the west. As shown by the section along the creek, this bench is composed for the most part of schist, over the surface of which is a gravel deposit of varying thickness, laid down by Glacier Creek at a time when the bench surface was the valley bottom, before the present stream canyon was eroded. To mine this bench a ditch was built to tap Glacier Creek at the lower end of claim No. 16. The width of the bench below the ditch line at the lower end of claim No. 14 is about 200 feet. Mining was done by running successive cuts from the ditch to the edge of the bench, and the tailings were discharged over the bench into Glacier Creek. The gravels on the bench surface ranged from 3 to 20 feet in thickness and were frozen in places, so that it was necessary to strip the cut and allow the material to thaw for a while before the loosened material could be removed. In working down the valley an old channel on the bedrock surface of the bench was found, diverging to the northwest, away from Glacier Creek. Along this channel the gravels became constantly thicker, and mining was discontinued at the point where the channel passed so far below the surface of the bench gravels that the bedrock would no longer drain to Glacier Creek. It is reported that the bench gravels worked yielded a good profit to the miners, but the increasing depth of the ground and the difficulties in keeping the ditch in repair so increased mining costs that no mining on this bench has been done for several years.

Claim No. 12.

Two men were mining on the upper end of claim No. 12 with pick and shovel. A cut about 240 feet long had been groundsluiced and most of the material shoveled into the boxes. The gravels, which lie on schist bedrock, average 6 feet in thickness and contain comparatively few boulders. Although one nugget valued at $80 is said to have come from this claim, most of the gold is comparatively fine, and nuggets are not common. It is reported that only a small part of this claim has been mined.

Other mining on Glacier Creek.

Since 1905 considerable mining has been done on Glacier Creek on claims that were not being worked in 1916. Some mining was done on claim No. 13; claims Nos. 15, 16, and 17 were largely exhausted; and claims Nos. 18, 19, and 20 all produced some gold. Certain claims on Yellow Creek are said to have been fairly rich, but they, too, were mined out. A good deal of prospecting and a little mining have been done on the claims below No. 12, but except on the stream flat through a canyon extending for about a mile below Discovery claim and that in another canyon just above the mouth of the stream, the stream gravels are so deep that ordinary mining methods fail to reach bedrock. The deep ground is said to begin on claim No. 11. It is reported that an 80-foot prospect hole sunk on claim No. 10, a 90-foot hole on claim No. 9, and an 80-foot hole on claim No. 7 all failed to reach bedrock.

CARIBOU CREEK.

Caribou Creek in its upper portion flows almost due west and is fed from the south by a number of tributaries that drain the highest peaks of the Kantishna Hills. At 10 miles below its head Caribou Creek swings to the north, and thence it flows between broad gravel-topped ridges to its confluence with Bearpaw River.

The only ground in the Caribou Creek basin on which mining was done in 1916 comprises a group of eight claims extending along the valley of Caribou Creek from Last Chance Creek to Crevice Creek. The area that has been mined is a strip extending 1,200 feet upstream from the mouth of Last Chance Creek and ranging in width from 10 feet through the canyon to 70 feet at the upper end of the cut, where the creek flat widens above the head of the canyon. The gravels were from 2 to 3½ feet thick in the stream bed and reached a thickness of 7 feet on some of the bars. Large boulders, some of them so large that it was necessary to mine around them, were numerous in the canyon, but above it none too large for one man to handle were encountered. Sluice boxes 10 inches square in cross section and lined with pole riffles were set on a grade of 9 inches to the box length. Water is always sufficiently abundant in Caribou Creek at this place for pick and shovel mining. In fact, inconvenience is more likely to result from too much rather than from too little water. The slopes in the basin of Caribou Creek are so steep that the stream responds quickly to any rainfall, and a heavy rain is likely to so flood the stream that mining must be suspended until the stream falls. The gold occurs throughout the thickness of the stream gravels but is especially concentrated on bedrock. That in the gravels is bright and yellow, but most of that on the bedrock is darkly stained and discolored. The gold taken from the canyon is coarse, the largest nugget found having a value of $110. That found above the canyon is fine and occurs in flat, flaky pieces. It is said to assay $13.50 an ounce. Associated with the gold in the sluice boxes are pebbles of magnetite, ilmenite, and the calcium tungstate scheelite and numerous large garnets. Four men were employed throughout most of the summer.

Very little mining has been done on Caribou Creek and its tributaries, except that on the group of claims just described. A small amount of gravel has in former years been sluiced on claims Nos. 3 and 4, and a good deal of prospecting has been done both in the stream gravels and on the high benches. The benches are said to carry promising quantities of gold, but the bench gravels are frozen, and the cost of thawing has so far prohibited mining on them.

LITTLE MOOSE CREEK.

Little Moose Creek is a small western tributary that joins the Clearwater Fork of Toklat River 3 miles above its mouth. For its entire length it flows through a deep, narrow valley bordered by rugged mountains of schist. The only mining in progress on this stream in 1916 was at a point 5 miles above its mouth, on claim No. 20, where two men were working. An automatic dam had been constructed, but it was not completed until late in the spring, and by that time the water supply had become too small for the most satisfactory operation of the dam. In the mining done in 1916 no bedrock had been uncovered by the middle of August, though some gold had been recovered from the gravels. Large boulders are confined almost wholly to the surface gravels, the deeper gravels being almost free from them.

It is reported that, except on claim No. 7, the gravel is so deep on all the ground below claim No. 18 that bedrock can not be reached by ordinary methods of open-cut mining.

Some mining has been done in past years on claims Nos. 18 and 19. It is reported that the stream gravels range from 8 to 10 feet in thickness, although in many places slide material from the valley sides has covered the pay streak to so great a depth that mining costs are prohibitive. The gold is coarse and shotty and not greatly worn. Although one-third of the gold recovered is said to be in pieces worth 50 cents or more, very large nuggets are not common, the largest taken from this creek having a value of $20. The gold is of low grade and is said to assay about $12 an ounce. Small nuggets of native silver are said to be present in almost every clean-up.

The creep of soil and talus is especially rapid in this creek valley and in those of adjacent streams. The small excavations made in the course of placer mining have at times been sufficient to disturb the equilibrium of the adjoining valley slopes, and large quantities of muck, soil, and coarse rock have suddenly slid into the mining cuts, burying sluice boxes and causing much annoyance. The unusual depth of the stream gravels in this valley is due, at least in part, to the rapid downward creep of detritus from the valley sides, which fills the valley floor more rapidly than the small stream can remove it.

PROSPECTS.

In the foregoing description of mines in this district all claims are included on which active mining was in progress in August, 1916, and some mention has been made of the results of mining in earlier years on ground that was not being worked at the time of visit. It is inevitable, however, that in a camp where so many men have come and gone and where the only record of past developments is in the memory of those men who have remained the record of mining should be incomplete. During the two years following the first gold discovery in this camp and the attendant stampede a large amount of prospecting was done on all the streams that drain the Kantishna Hills as well as in adjacent regions. The evidence of the work of those prospectors is everywhere to be found, in old cabins, prospect holes, and pits. As a result of their work the distribution of paying gravels, under the conditions then prevailing, was proved to be limited to the streams described above. Placer gold was, however, found widely distributed, and in many places it occurred in quantities almost sufficient to warrant mining at that time. Unfortunately, most of the information these men obtained at so great a cost of money and effort is now lost. With the better transportation that will be made available by the completion of the Government railroad along Nenana River mining costs may be so reduced that placer gravels heretofore unavailable may be mined at a profit.

Among the streams in the district that may become productive in the future are Rainy and Spruce creeks, tributaries of upper Moose Creek from the south; Myrtle, Moonlight, Stampede, and Crooked creeks, all eastward-flowing streams tributary to Clearwater Fork or to Toklat River; Flume Creek, which flows northwestward from the south end of the Kantishna Hills to Bearpaw River; and a number of headward tributaries of Bearpaw River. On all these streams coarse gold has been found in encouraging quantities. By simple panning, with little preliminary excavation, members of the Geological Survey parties found coarse gold in nuggets ranging in value from 10 to 30 cents on at least three streams on which no mining had been done. Numerous coarse colors were found on the benches of Clearwater Fork of Toklat River, and prospectors report that gold may be found at many places between Toklat and Nenana rivers.

TOTAL PRODUCTION OF PLACER GOLD.

The task of estimating the amount of placer gold that this district has produced presents many difficulties, and any estimate made can be considered accurate only in so far as it represents in a general way the volume of gold produced from this camp. Mining operations have been carried on by many men for a period of 12 years, and no accurate record has been made of the gold production. It has therefore been possible only to obtain estimates of the production from the men most intimately acquainted with the developments on the several creeks and by comparing and combining these estimates to arrive at an approximate figure. The total production of placer gold in the Kantishna district to the end of 1916 is here estimated as $380,000. This figure will appear too small to many persons, for there is a constant tendency among most miners to overestimate the production on the creeks with which they are least familiar. About half of the total output, however, was mined by men from whom exact figures were obtained, and it is believed that the total is not more than 10 per cent in error. The annual production for the last few years has been between $30,000 and $40,000.

FUTURE OF PLACER MINING.

No attempt at placer mining by other than the simplest methods has ever been made in this district. The difficulty of access to the region is perhaps the main cause of the failure to apply hydraulic or mechanical methods to the working of the gravels, but the small size of most of the rich creeks and the small amount of ground to be worked on any one claim have also favored the elastic methods of pick-and-shovel mining. At present, however, the richest of the shallow gravel deposits have already been worked out. For the leaner but more extensive deposits of gravel remaining more elaborate methods must be employed, but for the man with sufficient capital and an understanding of the problems involved the installation of a hydraulic plant, mechanical elevators, or a dredge may result in vastly greater profits than those gained by the man with little equipment aside from his own muscle and resourcefulness. It has been shown that the creek flat and benches of Moose Creek below Eureka Creek contain locally enough gold to pay for mining by hand methods. Systematic prospecting may show that these gravels are extensive and valuable enough to justify the installation of a hydraulic plant or a dredge. Similarly both the bench gravels and the stream flats of lower Glacier and Caribou creeks are known to be gold bearing and may some time yield a profit if mined on a large scale. Extensive gravel deposits on Clearwater Fork may also prove to be sufficiently rich to justify extensive mining. The success of any such large operations will depend, however, upon thorough and systematic prospecting to determine the value, extent, and physical character of the gravel deposits; upon the careful and wise choice of the proper equipment for mining; upon a close determination of the probable costs of operation; and, last but by no means least, upon wise and honest supervision and control.

LODE DEPOSITS.

GENERAL FEATURES.

Although no ores from lode deposits within the Kantishna district have yet been reduced, and no metal has been commercially recovered from them, there has been much active prospecting for lode deposits within the last few years; a number of veins containing gold, at least one carrying much silver, and three held for their antimony content have been discovered, and varying amounts of development work have been done on them. The prospective value of the lodes in this district can not be judged by the fact that they have so far yielded no production. Their remote situation and difficulty of access have delayed their development. Most of those who have prospected for lode deposits have been men of small means, without financial backing to undertake extensive underground mining or the erection of milling plants. The time and effort required to reach the lode prospects in summer have prevented the visit of many capitalists who might have undertaken the financing of mine development. The completion of the new railroad to the Tanana Valley, however, is likely to bring a new phase of mining activity to this district. Although no single vein has so far been developed to the point where the success of a mine is assured, there are nevertheless a number of prospects that are of sufficient promise to warrant thorough exploration and are likely some day to bring this camp into the list of gold lode producers.

All the lodes that have been considered worthy of any development occur within a rather small area. They lie along the highest part of the Kantishna Hills and are included in a belt 27 miles long and 6 miles wide, extending from Clearwater Fork of Toklat River in a S. 60° W. direction to and across Moose Creek. It is not certain, however, that other valuable lodes do not occur outside of the belt just described. There is abundant quartz float outside of this belt, but in the higher and more rugged mountains the steep slopes and the absence of a continuous surface covering of vegetation have rendered prospecting easiest, and most of the prospects lie high on the ridges. There is reason to expect that more intensive prospecting in the future will disclose the presence of many other veins at lower altitudes.

All the lodes so far found occur in similar geologic surroundings. The prevailing rock throughout the district has been called the Birch Creek schist, as it is believed to be a part of the same schist series that crops out in the area between Yukon and Tanana rivers. This schist is a highly metamorphosed rock, much folded and contorted and showing a variety of phases from place to place. A common phase is a dense quartzitic rock, locally rather massive but commonly showing much mica and exhibiting a more or less well-developed schistose cleavage. Fine silvery mica schists with highly developed cleavage are common and in places are studded with garnets. Dark carbonaceous schists and greenstone showing various degrees of metamorphism are also present. The general strike of the foliation of the schist is northeast, and dips at all angles may be found, as the beds are in general closely folded.

The larger quartz veins, including those whose principal valuable metals are gold, silver, and antimony, all cut the Birch Creek schist. There is a marked uniformity in the direction of strike, the main veins so far exposed all trending between N. 45° E. and N. 70° E. Although this trend is parallel to the general structure of the schist, most of the veins cut across the foliation of the schist that incloses them. The ore-bearing veins dip steeply, from 50° to 90°, and so far as can be made out hold their direction of strike and angle of dip rather constantly. They thus fall into a different category from the numerous lenticular and distorted veinlets and stringers of quartz that are so common in the schist which lie parallel to its foliation. The ore-bearing veins here described therefore occupy fissures that were opened and filled after a large part of the regional metamorphism to which the schists have been subjected was completed. There has been some movement along the vein openings since the ore was deposited, but this may be ascribed to local uplift or warping, for the veins themselves have not been notably deformed. The study of the ore deposits was hampered by the meagerness of the underground workings. The 11 longest tunnels aggregate 891 feet, and the two shafts only 70 feet. The longest tunnel is 188 feet from portal to breast, and 5 tunnels are over 100 feet long. Several of the tunnels are now caved in so that an examination was impossible. In addition to the underground workings the veins have been exposed by a large number of open cuts, but most of these were slumped and a thorough examination of the veins in them was impossible without clearing them, time for which was not available.

The different veins examined vary widely in the abundance of their metallic minerals and also in the proportions of those minerals in respect to one another. The assemblage of minerals, however, is much the same in all the mines. The more important minerals recognized were gold, silver, arsenopyrite, pyrite, galena, sphalerite, stibnite, and chalcopyrite. All these minerals are considered to be primary minerals—that is, they were brought into the veins directly by the ore-bearing solutions or were the result of chemical action between those solutions and the inclosing country rock. At the outcrops of the veins there is in places a shallow zone in which leaching and oxidation have been in operation and secondary minerals, such as iron oxide and lead carbonate, are found; but this surficial zone of weathering is shallow and tunnels driven into the quartz veins show unaltered vein material only a few feet beneath the surface. Along some open cracks and in places where the ore is shattered and broken the effects of oxidation and weathering have penetrated more deeply.

There are no facilities in the Kantishna district for having assays made, and such ore samples as are taken out for assay by the prospectors are in general sent to Fairbanks. The lack of easy transportation has made communication with Fairbanks infrequent, and there is a long delay between the time of collecting the ore sample and the receipt of the assay returns. This has resulted in rather haphazard prospecting, for the prospector, having found a promising-looking quartz ledge, may spend several months in development work before the receipt of his assay returns confirms his judgment or brings him disappointment. As a consequence of the difficulties in procuring assays, the prospector has been forced to rely upon such simple methods of determining the value of the ore as he has at hand. The most commonly used of these methods is to grind the ore in small hand mortars and pan the pulp thus obtained. This procedure serves, in a way, to determine the presence or absence of free gold, but the quantitative results are uncertain and may be misleading. Only a small piece of vein material can be crushed at a time, and because of the labor involved the prospector is likely to crush only what he deems to be the most promising pieces of ore and thus to raise false hopes as to the average value of his ore body. It is only by taking large samples across the entire vein at frequent intervals that a determination of the average content of the vein may be obtained. Furthermore, tests made by mortar and pan give no information concerning the gold in the ore that is not in the form of free gold. Most gold-bearing sulphide ores contain a certain percentage of gold so entangled with the sulphides that it can not be released by simple crushing and amalgamation, but for its recovery requires chemical treatment or smelting. The amount of gold so carried may be sufficient in quantity to justify mining. Reliable assays should be made to obtain definite figures on the value of the ore, in order to ascertain whether or not the opening of a mine and the construction of a mill are justified.

As already stated, comparatively few assays of ores from this district have been made, and most of those are not available for publication. One or two mining engineers have made rather thorough examinations of certain properties and have collected average samples from the ore bodies, but naturally their assay returns are not to be had for general use.

Difficulty is encountered by the prospectors in this district in keeping their tunnels in repair from year to year. A short distance below the surface permanent ground frost is encountered, and most of the tunnels when driven, in winter, are dry. After a tunnel has been opened, however, melting begins on the advent of warm weather, and ground that at first was solid and required no timbering begins to slump. As a result many tunnels are now caved in and inaccessible. It has been found, however, that tight bulkheads and close-fitting doors to cut off the circulation of air keep the tunnels frozen in summer. If underground work is done in summer and artificial ventilation is necessary, this tendency of the ground to thaw and slump is likely to necessitate the placing of heavier and more numerous timbers to keep the workings open and safe.

In the following pages the veins are described in the order in which they occur from east to west.

GOLD-LODE PROSPECTS.

MAMMOTH CLAIM.

At the head of Crevice Creek, a tributary of Caribou Creek, an open cut has been excavated on the Mammoth claim, situated high on the side of Spruce Peak, about 500 feet below the summit. This cut was reported to have slumped in and so was not visited, but it is said that there is at that place a large mineralized quartz vein. No figures concerning its gold content were obtained.

LLOYD PROSPECT.

On the east fork of Glen Creek a short distance above its mouth a tunnel has been driven 24 feet into the face of a cliff on the north side of the stream. At the tunnel mouth the cliff face shows a large amount of siliceous material that seems to be a rather pure quartzite, interbedded with the schist. Both the inclosing schist and the quartzite have been twisted into a close sigmoid fold that at one place gives a vertical exposure of quartzite 18 to 20 feet high. The quartzite has been mineralized, and some vein quartz has been introduced into it. Pyrite, chalcopyrite, and sphalerite were recognized, and gold is said to be present. It is reported that no work has been done on this claim for several years.

HUMBOLDT PROSPECT.

The Humboldt claim lies at the head of the east fork of Glen Creek, on the high ridge that forms the crest of the Kantishna Hills at this place. The schist here strikes N. 37° W. and dips 27° SW. A tunnel said to be 48 feet long, driven in a westerly direction, was so caved in at the time of visit that it could not be examined. It was apparently started on the cropping of a vertical quartz vein that strikes N. 55° E., but it is said that the tunnel diverged from the vein and that no quartz showed at the breast. The main vein is 3 to 4 feet wide and consists of milky white to somewhat stained and rusty quartz. The vein is massive and shows no noticeable banding but contains some small inclusions of schist. No metalliferous minerals, except iron oxide, were noted, although galena and sphalerite are reported. Associated with the main vein are two or three other smaller parallel veins, all lying within a zone that measures about 30 feet across. Numerous large pieces of the vein quartz, broken from the croppings, lie about on the surface near the tunnel mouth, and it is said that several hundred pounds of this surface ore was shipped to Fairbanks for treatment and yielded promising returns, mostly in free gold. A tent and blacksmith shop have been erected at the tunnel mouth, and another tent stands in the valley below. No one was working on this property at the time it was visited (August, 1916).

SKOOKONA PROSPECT.

A number of open cuts have been excavated on the top of the high ridge about 1 mile east of Glacier Peak, where the schist strikes N. 20° E. and dips 15°–30° E. Several open cuts and a 12-foot shaft have been made on a large quartz vein that seems to lie parallel to the schistosity and apparently has a maximum thickness of 20 feet. It forms a capping for the ridge on which the cuts lie, and all the principal exposures may be upon the same vein. The quartz is characteristically milk-white, though in places it is stained by iron oxide. Little evidence of mineralization is to be seen. Not enough development work has been done to show positively the structure or relations of this quartz body.

GLEN PROSPECTS.

Two tunnels have been driven near the top of Glacier Peak, a high mountain on the ridge between the heads of Glen and Glacier creeks. At this place the schist strikes due north and dips 40° W. The upper tunnel, now caved in, is said to be 40 feet long, with a winze in the end. The lower tunnel was evidently driven to cut the quartz vein that crops out on the slope above. As judged by its shattered croppings the vein appears to be about 10 feet wide and to consist of white to gray banded quartz. Pyrite, sphalerite, and possibly galena were noted in the quartz on the dump. No evidence of recent work was seen, and no one was present on the property at the time of visit. It is said that the quartz carries promising amounts of gold, but no figures were obtained as to the average gold content.

McGONAGALL PROSPECT.

The McGonagall prospect, on a gold quartz vein, lies near the head of Glacier Creek, at an elevation of approximately 3,400 feet. A substantial cabin has been erected near the vein cropping. The vein as exposed by the outcrops and in an open cut seems to strike N. 70° E. and dip 50° SE., and it is said to show a maximum thickness of over 8 feet. A 12-foot tunnel, driven into the mountain at the vein cropping, is lagged except at the breast, which showed only schist. On the surface many large pieces of white quartz, some 2 feet in diameter, show iron oxide along the broken faces and inclose lenses and bunches of mica schist. Some finely disseminated pyrite was observed along small fractures in the quartz.

It is reported that the best ore so far found on this property was taken from a small quartz vein in the creek bed below the cabin. A ton of this ore has been shipped to Fairbanks for a mill test. No one was present on this ground in August, 1916.

GREISS PROSPECT.

The Greiss prospect comprises the adjoining Malachite and Azurite claims, both on the north side of upper Eureka Creek. On the Malachite claim a 13-foot tunnel has been driven on the north valley slope, opposite the upper end of placer claim No. 13. This tunnel, evidently driven to cut a zone of quartz-bearing schist, is timbered but shows in the breast black schist with small quartz veinlets.

West of the tunnel an open cut exposes black slate schist, finely banded and carrying numerous quartz veinlets lying parallel to the foliation of the schist, which strikes N. 45° E. and dips 30° NW. Pyrite, in cubes as large as a quarter of an inch in diameter, is locally abundant in both quartz and country rock. Tiny calcite veinlets cut across the schistosity. The quartzose zone in the slate schist is at least 4 feet thick and contains streaks of white clayey material full of quartz fragments. In the absence of the owner no other workings were found, and no information was gained as to the gold content of the ore.

EUREKA PROSPECTS.

A group of claims, said to be named the Eureka group but locally known as the Taylor property, lies on the north valley slope of Eureka Creek, about 3 miles above its mouth. These claims have been developed by the Lower Eureka and Upper Eureka tunnels and an open cut, and a cabin has been constructed near the mouth of a southward-flowing tributary of Glacier Creek. The Lower Eureka tunnel is situated on the north side of Eureka Creek, near the top of a steep bluff. It is timbered for 20 feet, but beyond the timbered part it is caved in. The total length of the tunnel is said to be 40 to 50 feet. This tunnel was driven on a mineralized zone that is about 8 feet wide and apparently strikes N. 25° E. and dips 80° NW. This zone has a distinct hanging wall, though the footwall is not well exposed. It contains abundant quartz which incloses numerous horses and lenses of schist, and the whole is much crushed and rusty, the broken quartz and schist being in part recemented by iron oxide. The inclosing schist strikes N. 15° E., and the tunnel is driven in a direction a few degrees east of north. The surface vein material is so oxidized and coated with iron rust that little evidence of other mineralization can be seen. Some pieces of quartz on the dump, however, show white quartz with finely disseminated pyrite, some galena, and a little stain of copper carbonate.

The Upper Eureka tunnel is over 600 feet above the lower tunnel and about 4,000 feet northeast of it. It was driven N. 67° E. for 100 feet and has three branches, the total length of underground workings being about 144 feet. The tunnel is driven along the strike of a vertical quartz vein. On its northwest side it follows the wall of the vein, and on its southeast side it has a straight, smooth parting in the vein for a wall. In the outer 100 feet of tunnel the vein quartz is shown to be at least 7 feet wide, and one wall of the vein is not exposed. There has been some movement along the contact between quartz and schist, as both schist and vein material are somewhat shattered and broken. The vein as a whole is fractured, and the broken surfaces of quartz are covered with iron oxide.

At 100 feet from the tunnel entrance another quartz vein at least 3 feet thick, striking N. 30° W. and dipping 20° SW., seems to cut off the main vertical vein on which the tunnel was started. Not enough work has been done to determine the relations of these veins.

The country rock at this place is a dense, quartzitic schist, containing mica and coarse granules of quartz. It strikes N. 30° E. and dips 24° NW. The vein material ranges from white glassy to gray mottled quartz, with some dark rock containing quartz and sulphides, much stained and discolored. Iron pyrite is widely disseminated through the vein filling, and locally abundant pyrite, sphalerite, and a little galena were seen. No report was obtained as to the gold content of this lode.

PENNSYLVANIA AND KEYSTONE PROSPECTS.

The Pennsylvania and Keystone claims are described together, as they adjoin each other, are held by the same owner, and are staked along the strike of veins that are continuous from one claim to the other. These claims, which lie on the north side of Eureka Creek, are crossed by Iron Creek, a small southeastward-flowing tributary of Eureka Creek. They have been developed by a large number of open cuts, although no underground work had been done at the time of visit.

The main vein on this property is a quartz vein averaging 3 feet in thickness, striking N. 50° E. and dipping 56° S. It crops out at the point of discovery on the Keystone claim and has been traced thence along the strike northeastward across Iron Creek and up the opposite side of that valley. About twenty open cuts made by stripping off the vegetation and loose surface material show that the vein is continuous and preserves its direction of strike, angle of dip, and thickness for at least several hundred feet along the outcrop. In the weathered surficial portions of the vein so far uncovered the quartz is broken and oxidized and generally rusty in appearance. Arsenopyrite and pyrite are abundant, and locally the quartz is heavily mineralized with arsenopyrite, sphalerite, and galena. Small pieces of vein quartz mortared and panned as a rule show free gold, and on many pieces of ore coarse particles of free gold can be distinguished with the unaided eye. Development work had not progressed far enough to disclose the vein below its weathered surface portion, and no assays of average samples of ore had been made.

In the valley of Iron Creek, 100 feet above the crossing of the vein just described, there is another quartz vein striking N. 54° E. and standing about vertical. This vein shows a maximum of 6 feet of quartz, 2 feet of which, on the southeast wall of the vein, is banded and broken. The quartz contains iron sulphides, and gold can be panned from its surface croppings. If this vein maintains a trend uniform with that at the place where it has been uncovered, it should intersect the main vein a short distance east of Iron Creek.

An open cut just east of Iron Creek, made to intersect the main vein, encountered a small quartz stringer three-fourths of an inch to 6 inches wide, in the oxidized portion of which were pockets of very rich gold ore. Several ounces of fine crystalline gold was panned from the decayed surface of this veinlet, and specimens were preserved that showed a spongy network of delicate gold crystals, any sulphides that may originally have been present having been leached out and oxidized. Only a small amount of this exceptionally rich ore was found in the small excavation at that place, and its relation to the main vein had not been determined, but its presence indicates the possibility of the existence of rich ore shoots in these veins.

GOLD KING CLAIM.

The Gold King prospect lies near the head of Iron Creek, high on the ridge between Eureka Creek and the head of Friday Creek. Development work on this claim consists of two tunnels, the lower of which, at an elevation of about 3,150 feet, is said to be 30 feet long but is caved 20 feet from the portal. It is reported that in this tunnel the quartz vein averaged 4 feet in width. About 50 feet above the lower tunnel, on the same vein, a second tunnel has been driven for 7 feet. Here the quartz vein, which strikes N. 70° E. and stands vertical, is shown to be over 6 feet wide, only one wall of the vein being exposed. The inclosing schist is fractured and disturbed but strikes about N. 80° E. and dips 20° S. The freshly fractured vein quartz is white and massive, although the croppings and the old fracture faces are stained with iron rust. Arsenopyrite, sphalerite, and galena were noted, and the oxidized croppings of quartz are said to assay several dollars in gold to the ton and to carry a trace of silver. The residual material on the surface is reported to show colors of gold on panning.

GOLDEN EAGLE CLAIM.

The Golden Eagle Claim is at the head of Friday Creek, on the ridge that separates the Friday Creek basin from that of Iron Creek, a tributary of Eureka Creek. The property is developed by several open cuts and by a tunnel. The open cut in which the first discovery was made showed a vein cropping 3 feet wide, of which 2 feet consisted of vein material heavily mineralized with galena, pyrite, sphalerite, and copper carbonates and containing considerable free gold. The tunnel was driven on a crushed and slickensided zone, to intersect the vein shown in the open cut. The inclosing schist there strikes N. 55° E. and dips 51° SE., and the crushed zone strikes parallel with the schist but dips at a steeper angle. The tunnel has a total length of 145 feet and shows bunches of quartz along the crushed zone, within which both quartz and schist are mineralized. The heavily mineralized vein material, which on the surface showed a width of 2 feet, in the tunnel averages only a few inches wide, with a maximum of 18 inches, but its gold tenor is said to be most encouraging. Tests made by crushing in a hand mortar and panning the pulp show abundant particles of free gold, and assays have shown gold to the amount of several hundred dollars a ton.

LITTLE ANNIE CLAIM.

The Little Annie claim lies on the northwest side of the Friday-Eureka Creek divide, a short distance below the summit. In addition to a number of open cuts this claim is developed by a tunnel with a total of 147 feet of underground workings. The schist country rock here strikes N. 18° W. and dips 15° W. The main tunnel trends south and was driven to intersect a vein which appears in an open cut on the hillside above. The main vein was encountered 90 feet from the portal, and a drift 42 feet long was driven S. 59° W. along the vein. A crosscut 60 feet from the portal runs S. 55° W. for a distance of 10 feet. The main vein consists of quartz, is from 3 to 4 feet thick, and dips 65° SE. The footwall is sharply defined and is much slickensided, with horizontal striations, showing that horizontal movement has taken place between the vein and the footwall since the quartz was deposited. The quartz contains disseminated pyrite and pans a little gold. No galena or sphalerite was seen in the underground workings, but these minerals are probably present, for pieces of solid galena several inches in diameter have been found on the surface near the outcrop of the vein. A piece of this float galena on assay yielded 124 ounces of silver to the ton.

Between the footwall of the main vein and the 10-foot crosscut there is a zone 27 feet wide, lying parallel to the main vein, in which the schist is so intricately cut by small quartz veinlets a few inches in thickness that more than half of the whole zone appears to be composed of quartz. Assays of the vein material have shown that the quartz carries a few dollars a ton in gold.

SILVER PICK CLAIM.

The Silver Pick claim lies southwest of the Little Annie and Golden Eagle claims, on the same ridge and at about the same elevation. It is developed by several open cuts and by a straight tunnel 188 feet long, driven S. 30° E. The schist country rock strikes S. 5° W. and dips 50° W. At the tunnel portal one edge of a quartz vein that panned gold was cut, but the thickness of this vein was not determined. At 54 feet from the portal a vein striking N. 35° E. and dipping 68° NW. was penetrated. This vein is 5 feet thick and is composed of rusty quartz containing numerous bunches of galena. A picked sample of this galena is said to have assayed several hundred ounces of silver to the ton, and the ore is said to carry a fraction of an ounce of gold to the ton.

The main vein near the breast of the tunnel consists of a 13-foot zone striking N. 35° E. and dipping 67° SE. and is therefore approximately parallel in strike with the vein already described but lies 130 feet to the northeast. It consists of a 1-foot layer of calcite on the footwall, above which is a 12-foot zone, more or less sheeted, of quartz and schist, the quartz predominating in bulk over the country rock. In this zone there is little galena to be seen in the tunnel, but galena is abundant along the outcrop of the vein. The whole zone is brecciated and leached, and large open cracks extend from the tunnel to the surface. Pyrite, arsenopyrite, and small amounts of galena and sphalerite were observed.

GALENA CLAIM.

The Galena claim lies on the northeast side of Moose Creek, on the end of the ridge that divides the Friday Creek basin from that of Eureka Creek. The development work consists of a number of open cuts, now caved in, and a tunnel, evidently driven to intersect a vein that was exposed in the open cuts. The tunnel, which runs S. 50° E., is 27 feet long and has a 6-foot crosscut at the breast, where a distinct plane of movement, with some gouge, strikes N. 45° E. and dips 63° SE. Adjoining the gouge-filled fracture and on the footwall side of it is a body of quartz, white to mottled with blue-gray patches, that is heavily mineralized with pyrite, arsenopyrite, galena, and sphalerite. Any one of these sulphides may occur in nearly pure bunches, or they may all be intimately intermingled. Galena was seen in nearly pure stringers 2 inches or more thick, and an assay of it yielded 131 ounces of silver to the ton.

There is no sharp break between ore body and country rock on the footwall side of the vein, the mineralization merely becoming less as the distance from the hanging wall increases. Veinlets of ore extend into the country rock but pinch out within short distances. So far as could be determined by an examination of the short stretch of the lode exposed in the crosscut, the heaviest mineralization occurred within 4 feet of the gouge-filled fracture. Exploration has not been carried beyond that fracture, and the presence or absence of ore beyond it has not been determined. The owner was not in the district at the time this property was visited, and the proportion of gold to silver in the ore is not known, although it is reported that gold is present, and the deposit is classed as a gold lode.

OTHER GOLD-LODE PROSPECTS.

Many lode claims in addition to those already described have been staked in this mining district, and on some of them the annual assessment work is done. Other prospects have been staked and later abandoned. It has been the intention of the writer to describe here only those properties that seemed of sufficient importance to the owners to warrant underground development or the excavation of sufficient open cuts to expose the vein. It may well prove, however, that some veins which have received little attention may upon exploration show great promise, and undoubtedly the district contains many veins that have not yet been discovered.

ANTIMONY LODES.

GENERAL FEATURES.

Within the Kantishna district there are several claims held for their content of the antimony trisulphide, stibnite. Genetically the antimony lodes are directly related to the gold lodes above described. The veins have the same association of minerals, but they contain antimony in large masses; whereas in the gold lodes antimony, although occasionally recognized, is a minor constituent. The presence of veins containing considerable masses of stibnite has been known since the first years of mining activity in this region, but the remoteness of the district and the prevailing low price of antimony prevented the exploitation of the antimony deposits, although a minor amount of development work was done on two of them. After the outbreak of the European war the price of antimony rose from 5 to 7 cents a pound to the unprecedented price of 37½ to 40 cents at the end of 1915. As a result of this great demand interest in the Alaska stibnite ores increased, and production began at several mines.[1] In the Kantishna district the response to the increased price of antimony was somewhat sluggish, for communication with that district is slow, and much uncertainty existed as to the value of antimony on any particular date.

Furthermore, it was not feasible to take ore to the navigable waters of Kantishna River except by sled in winter, and thence by boat the following summer to Tanana. Even from the Tanana several weeks would elapse before the ore could be delivered to a purchaser in the States. It is apparent, therefore, that at least three or four months and possibly a longer time must elapse between the date of mining antimony ore in the Kantishna district and its delivery at the market. When to the cost of mining is added the transportation charge of sled and small-boat haulage to the Tanana and of freight thence to Seattle or San Francisco, no great margin of profit is left for the producer even at the highest war prices. In addition to this high cost there was also to be considered the instability of the market and the possibility of a sudden drop in the price of antimony. At 40 cents a pound for antimony there might be a fair profit in shipping stibnite ore from this district. At 25 or 30 cents a pound the producer might face a serious loss. As a result little mining was done on stibnite ore in 1915, and none was shipped. In 1916 some ore was mined and stacked, but at the time of this writing no antimony from the Kantishna has reached the market.

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[1] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, p. 7, 1916.

TAYLOR MINE.

The Taylor mine, or, as it is commonly called, the Antimony mine, lies near the head of Slate Creek, a headward tributary of Eldorado Creek. The property was first staked in 1907, but the title lapsed, and the ground was restaked by the present owner. It is said to include a group of claims, but development work has been confined to the driving of a tunnel 97 feet long, with 22 feet of crosscuts, and to the excavation of an open cut immediately above the tunnel. As shown in the open cut and tunnel, a strong fissure along which movement has taken place strikes N. 50° E. and dips 82° SE., and this fissure limits in most places the southeastern extent of the main ore body, although a little ore appears on the southeast side of this fissure. The ore body has a maximum width of 15 feet and constitutes a reticulated stockwork of quartz and stibnite, with irregular bunches and horses of decomposed clayey schist, all much broken and confused. The inclosing quartzite schist strikes north and dips 28° E.

The stibnite occurs in veins and veinlets of almost pure stibnite as much as 2 feet wide, and also in irregular lenses and bunches. Some of it is solid and unaltered, but in other places the ore is crushed and broken and consists of small fragments of quartz and stibnite recemented by yellow and reddish secondary oxidation products that upon analysis are found to consist of the antimony ochers stibiconite and kermesite. The principal ore bodies, which occur within 6 or 8 feet of the main fissure, seem to lie in the stockwork obliquely to the main fissure, the ore lenses and veinlets in general dipping 60° NW. The stibnite occurs predominantly as aggregates of acicular crystals, but masses of fairly granular material are also present. The ore so far mined was estimated to consist of about 125 tons of hand-sorted stibnite. Most of this ore was taken from the open cut. That excavated from the tunnel was of lower grade, as it contained smaller bunches of pure stibnite and more quartz and schist. In the absence of facilities for machine concentration much stibnite that could not be separated from the gangue by hand sorting was thrown on the dump. Three men were employed on this property in 1916. A project was under way to bring in motor trucks to be used in hauling the antimony ore from the mine to navigable water on McKinley Fork of Kantishna River, at a point about 4 miles above the abandoned town of Roosevelt, from which the ore was to be taken by small boat to Tanana River.

CARIBOU LODE.

In the basin of Caribou Creek near the mouth of Last Chance Creek, a tributary from the southeast, there is a stibnite-bearing lode on which some development work has been done. This lode was visited by Prindle[1] in 1906, and the following description of the property is made from information procured by him and by the writer. Little work has been done on it since 1906, and at the time the property was visited in 1916 the shafts were full of water and inaccessible. The property consists of two lode claims, the Pioneer and the Caribou, which lie across the lower valley of Last Chance Creek. Two shafts have been sunk, one 40 feet deep on the west bank of Last Chance Creek and another 30 feet deep on the east bank. The vein strikes N. 40° E. and dips about about 67° SE. It is approximately 4 feet wide and consists of a mixture of quartz and stibnite. In the western shaft a vein of pure stibnite 1 foot wide is said to lie along the northwest wall and to become narrower toward the bottom of the shaft. The quartz is massive to crystalline and is intimately intergrown with the stibnite, which occurs as a mixed aggregate of fine-grained, massive sulphide intermingled with acicular crystals 2 inches or more in maximum length. Within the coarsely crystalline stibnite there are many long individual quartz prisms lying parallel with and surrounded by the stibnite. The country rock inclosing the vein is hornblende schist, which is much contorted, but which in the main strikes N. 65° E. and dips 35° NW. On Caribou Creek, several hundred feet northeast of the shafts, is the outcrop of a fissure striking N. 45° E. and dipping 75° SE., which is believed to be the continuation of the antimony lode but which at that place shows only a little quartz.

Three samples of antimony ore collected from this property in 1906 were assayed. One yielded 4 ounces of silver to the ton, one

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[1] Prindle, L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, p. 219, 1906.

2.76 ounces of silver and 0.12 ounce of gold, and the third 0.12 ounce of gold but no silver. Another sample, assayed for gold only, yielded 0.02 ounce to the ton. No ore from this lode has been marketed.

STAMPEDE LODE.

About 2 miles above the mouth of Stampede Creek, a tributary of Clearwater Fork of Toklat River from the southwest, on the southeast valley wall, a claim has been staked on a lode deposit of stibnite, here called the Stampede lode. The only development work that has been done is the excavation of a large open cut in 1916. The country rock, a reddish quartzite schist, at the nearest outcrop to the lode that seemed undisturbed strikes northwest and dips 30° NE. At the lode outcrop, near the top of a rounded ridge, the surface is covered by a mantle of disintegrated rock, and the schist itself is much disturbed by frost and by creep, so that it is difficult to ascertain the relation between the ore and the country rock. In the floor of the open cut and exposed at its face is a large body of nearly pure stibnite, apparently at least 12 feet thick across the vein. The ore in the face of the cut was faulted and slickensided, and no good exposures of the contact of ore with schist were seen. A little quartz is present in the ore, but one man had in three weeks removed and stacked 40 or 50 tons of selected stibnite almost entirely free from visible gangue or impurities, much of it in lumps 6 inches to 1 foot in diameter. The vein in which the stibnite occurs, probably as a large lens, strikes northwest and apparently dips 65° SW. A branch vein of stibnite is seen by the distribution of broken surface ore to strike northeast. The stibnite is mostly in the form of a close-grained, massive aggregate in which small scattered crystals may be distinguished. Some more coarsely crystalline stibnite is also present, but in subordinate amounts. It is reported that a sample of ore from this vein showed on assay 69.8 per cent of antimony, 1 per cent of arsenic, and no silver or lead.

Another vein carrying stibnite with much intermingled quartz is said to crop out on the opposite side of Stampede Creek along the general direction of strike of the Stampede lode, but no development work has been done on it.

LIGNITE.

OCCURRENCE.

Tertiary deposits containing lignitic coal occur at intervals throughout the area considered in this report. They are widespread just east of Nenana River, in the Nenana coal field, where deeply cut valleys expose numerous beds of lignite. The coal-bearing beds are overlain, in the Nenana field, by a heavy body of oxidized gravels that in many places seems to rest conformably upon them. West of Nenana River, in the Kantishna area, outcrops of both the coal-bearing beds and the succeeding gravels are found here and there near the north flank of the Alaska Range, at least as far westward as the headwaters of Bearpaw River, and at some of these localities beds of lignite occur. No single exposure discloses lignite in the abundance in which it is found in the Nenana field, and it is doubtful if such beds are to be found elsewhere. The area of coal beds and the quantity of lignite coal west of Nenana River, however, may be out of proportion to the amount to be seen in the outcrops. In this area the beds are not generally dissected by deep valleys with bare walls, as on Lignite and Healy creeks, but are bared by the cutting of small gullies. Furthermore, a widespread blanket of later gravel deposits covers the coal-bearing areas, so that outcrops are scarce and poor. The widespread geographic distribution of the localities in which beds of the coal-bearing series occur, however, and the presence in these beds of lignitic coal at widely separated localities, indicate that there may be present beneath a covering of younger materials a much larger quantity of lignite than is now known.

In the following paragraphs is given a brief description of the localities west of Nenana River at which beds of lignite were seen.

TEKLANIKA BASIN.

SAVAGE FORK.

A number of exposures of lignite were seen in the basin of Savage Fork, the eastern branch of Teklanika River. The southernmost of these occurs near Ewe Creek, a small westward-flowing tributary that drains the north slope of the schist mountains north of the divide between Dry Creek and Savage Fork. About a mile above the mouth of Ewe Creek, on its north side, is a prominent light-colored bluff composed of decayed schist and blue-white clays. Just east of the bluff, at the mouth of a small southward-flowing stream, a 2-foot bed of weathered lignite is exposed, but its relations are obscured by vegetation and waste material. A few hundred yards up the same small gulch a 10-foot bed of lignite striking about east and dipping 30° S. forms a waterfall in the gulch. As the schist crops out only a short distance north and south of this exposure, it is probable that the area underlain by coal at that place is small.

On the north side of Ewe Creek, extending from its mouth eastward for nearly a mile, a bed of lignite showing a maximum observed thickness of 9 feet crops out at intervals at the edge of the stream flat. The relations of the lignite to the overlying and underlying beds are not exposed. The bed strikes N. 75° E., and as it dips about 20° N. beneath the broad benches north of the outcrop, it may have an area of several square miles. The lignite was free from partings and appeared to be of about the same grade as the average lignite of the Nenana field.

On the west side of Savage Fork, about a quarter of a mile below the mouth of Ewe Creek, an imperfect exposure in the stream bluff shows a short section of a 14-foot lignite bed, which strikes N. 85° E., dips 15° N., and is overlain by 40 feet of cross-bedded sandstone. The coal-bearing beds are covered unconformably at the top of the bluff by 8 feet of coarse yellow gravel, above which lies 20 feet of fine gravels. About 1½ miles below this outcrop an excellent exposure along the same bluff shows a total of 25 feet and 8 inches of lignite in five beds, as indicated below:

Section of lignite-bearing beds on Savage Fork 1½ miles below the mouth of Ewe Creek.

	Ft.	in.
Terrace gravels	15	0
Unconformity.		
Clay	24	0
Lignite	6	0
Clay	1	6
Lignite	9	0
Clay	2	0
Lignite	1	2
Clays, sands, and silts	32	0
Shale	3	0
Gray sandstone	3	0
Lignite	3	6
Dark-gray shale	2	0
Light-gray shale	3	0
Dark-gray shale	2	0
Gray sands	4	6
Dark-gray shale	3	0
Gray sands	3	0
Lignite	6+	

These beds at the south end of the exposure strike about N. 20° W. and dip 10° W., but toward the north end the dip steepens in a sharp flexure. There a lignite bed, poorly exposed but apparently 5 or 6 feet thick, crops out and is seemingly at a higher stratigraphic position than the top of the section given above. The whole coal-bearing series is covered unconformably at the top of the bluff by terrace gravels. On the east side of Savage Fork, a short distance above the exposure just described, a bed of lignite, much disturbed by surface creep but apparently 8 feet thick, crops out in a small tributary valley. Its relations are not clear, but it is probably to be correlated with one of the beds in the section given above.

The numerous lignite outcrops observed in this portion of the Savage Fork basin, between the schist hills on the south and the high gravel ridges on the north, indicate that there is at this place an area of probably several square miles that is underlain by lignite in beds of workable thickness. Time was not available for the careful structural work necessary for outlining the probable extent of the several lignite beds.

A little impure lignite was observed in the east bank of Savage Fork about 1½ miles above its mouth, but no considerable lignite beds were seen there.

SANCTUARY RIVER.

On the east side of Sanctuary River 3 miles above its mouth a 15-foot bluff along the stream shows a 3-foot lignite bed, interbedded with gray clays and gravels. The beds have here been compressed into an anticlinal fold, on the north flank of which the lignite dips downward below the stream level. The general strike of the anticline is east.

TOKLAT BASIN.

EAST FORK OF TOKLAT RIVER.

The East Fork of Toklat River is formed by the junction of a number of northward-flowing streams that drain from the crest of the Alaska Range. Below their confluence there is a considerable amount of lignite upon the stream bars in pebbles and in small piles of fragments formed by the weathering of larger pieces. The source of this material was not ascertained, but it is almost certainly in the basin-like depression that forms a low divide extending from a point near the head of East Fork of Toklat River to the Toklat at its forks.

TOKLAT RIVER.

On Toklat River near its upper forks a low pass connects that basin with the valley of upper Stony Creek. Three miles above the mouth of the stream flowing eastward from the pass three beds of lignite, from 1 to 4 feet in thickness, cropping on the south side of the stream were seen by members of the Survey party but were not visited by the writer. In the same valley, about 1 mile above the mouth of the stream, a bluff composed of the shales, gravels, and sands of the coal-bearing series shows a 2-inch bed of impure lignite.

KANTISHNA BASIN.

Moose Creek, a headward tributary of Bearpaw River, in the Kantishna basin, heads in the high mountains 9 miles northeast of the terminus of Muldrow Glacier. Near the extreme head of this stream there is a basin-like area floored with beds of the Tertiary coal-bearing series, and a number of exposures show thin beds of carbonaceous material and impure lignite. At one locality near the Moose Creek-Stony Creek divide, on the north side of the valley and 350 feet above its floor, is the weathered outcrop of a 12-foot lignite bed, which strikes N. 80° E. and dips 55° S. This bed seems to lie near the base of the coal-bearing series at that place and overlies a purple, discolored shale, beneath which is volcanic material. The lignite croppings were observed for a short distance along the flank of the mountain, but the areal distribution of this bed is not known, though its structural relations indicate that it dips beneath the beds to the south, and in this basin it may possibly have an area of a few square miles.

Lignite fragments were seen also 6 miles below the lignite exposure just described, in the stream gravels of the northeast fork of Moose Creek. A hasty examination failed to disclose the bed from which the scattered fragments were derived, but it is reported that a bed of lignite 10 feet thick is exposed along the south bank of that stream about 2 miles above its mouth. Coal from this place has been taken to the placer mines on Moose Creek and is said to be of fair quality. Lignite is also reported to occur in the canyon along the north edge of Muldrow Glacier, a few miles above its terminus.

Some fragments of lignite were noted on the bars of Glacier Creek about 1½ miles above its mouth. The deposit from which they were derived was not seen, but it is evident that the coal-bearing formation is present in this locality, although for the most part covered by younger gravels.

GOLD PLACERS OF THE ANVIK-ANDREAFSKI REGION.

By G. L. Harrington.

INTRODUCTION.

The Anvik-Andreafski region, as considered in this report, embraces the territory north and west of the lower Yukon River, between Anvik and Andreafski rivers. The area covered by surveys in 1916, extending from longitude 159° 40′ to 163° 20′ W. and from latitude 61° 30′ to 63° 40′ N., is approximately 2,000 square miles.

Topographic and geologic traverses were made on the Yukon from Anvik to Andreafski and up Anvik, Bonasila, Stuyahok, and Andreafski rivers as far as was practicable under the limitations of the short season. The intervening stretches of country that were inaccessible from the boat were not visited. Sixteen days was also spent in the vicinity of Marshall in studying the mineral resources and in topographic and geologic mapping.

The work was in charge of R. H. Sargent, topographic engineer, the writer being attached to the party as geologist. C. F. Bailey and C. E. Anderson acted as recorder and cook, respectively.

The writer wishes to express to each member of the party his appreciation of their cordial aid in the furtherance of the geologic work. To Mr. Sargent especially he feels under great obligations for hearty cooperation both in the field and in office work. Cheerful acknowledgment is made of the indebtedness of the members of the party to Rev. J. W. Chapman and others at Anvik, who assisted in the preparation for field work. To every miner, prospector, and merchant met during the summer thanks are due for hospitality and cooperation.

RELIEF.

GENERAL CHARACTER.

In general the relief of the region is moderate. The highest point attains an altitude of about 2,700 feet, and there are comparatively few small isolated areas lying above 2,000 feet. Along the west and north bank of the Yukon there are in places sharply dissected areas, but as a whole the forms are those of a mature topography, so that the country presents a rolling aspect. Quite as extensive as these uplands are the wide, poorly drained lowlands that occupy the intermontane areas.

UPLANDS.

The uplands are scarcely of sufficient elevation to merit the term mountains, although here and there a point rises well above the general level and furnishes a conspicuous and easily identified landmark. Of this character are Bonasila Dome, Chiniklik, and Pilcher Mountain.

Bonasila Dome lies east of the Stuyahok and south of Bonasila River, and its isolation, together with its peculiar form (a cone on the crest of a gently crowning dome), gives it prominence from whatever point it is seen. This peak is also called Simel Mountain.

The peak known by the guttural native name Chiniklik, frequently corrupted by the whites to Cheneegly, though the highest and most conspicuous peak in the area, is only 4 miles from the Yukon. It lies 8 miles above Russian Mission and 12½ miles below Tuckers Point. This mountain was seen from points along Anvik River, from Andreafski, and from practically all the intermediate stations, except those at the water's edge on the banks of the Yukon. Its conical outline, with shoulders a few hundred feet below the apex, readily identifies it. This peak is visible from many points along the crest of the divide between the Yukon and Andreafski drainage basins and from points far south of the Kuskokwim.

Pilcher Mountain, about 5 miles east of Marshall, rises well above the immediately adjacent hills and is topographically prominent because of the exceptionally well developed altiplanation terraces on all sides but the east.

The softer sedimentary rocks of Mesozoic age are everywhere, except near the Yukon, marked by the gentle slopes and rounded crests that are characteristic of a mature topography. Elsewhere the drainage is that of an area past maturity in the cycle of erosion, but the crests of the hills present a terraced appearance. The origin of these forms has been described by Eakin,[1] who termed the process altiplanation. These terraces are best developed in the areas of igneous rocks at the higher elevations. To a minor degree altiplanation has taken place in some of the more indurated sedimentary rocks, especially in the vicinity of intrusives.

LOWLANDS.

The lowlands may be subdivided into two classes—the lowlands that lie above the flood level of the Yukon and those that are influenced by its highest stages. The first class includes the broad plains that are here characteristic of the tributary valleys of the Yukon. Bedrock crops out along the streams only here and there and not at all for several miles above their mouths. Alluviation has proceeded so far that, except in their headward portions, the streams flow in meandering courses with many oxbow sloughs formed by abandoned meanders. In the area which lies within the influence of the Yukon are to be placed the wide stretches of lowland that extend to the Kuskokwim, east and south of the Yukon. The gradients of the larger tributary have been lowered to such an extent by alluviation that they are controlled by the Yukon at all but the lowest stages. Five miles up the Bonasila was seen débris which undoubtedly came from the Yukon. It is, therefore, conceivable and even probable that the alluvial material, which is now being laid down over the bottom lands in the lower reaches of this and other tributaries, is in large part derived from the overloaded flood waters of the Yukon, which deposit a considerable portion of their burden in the slack water of the embayments furnished by these stream mouths.

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[1] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, p. 78, 1916.

DRAINAGE.

To the geologic structure was due the original position and direction of many of the streams, but other factors have affected their later history, and the former courses have been somewhat modified by alluviation and lateral erosion. The valley occupied by Stuyahok, Bonasila, and Anvik rivers affords an excellent example of stream trend initially controlled by the underlying bedrock structure, and the Yukon, above Holy Cross, trends in the same general direction. Structural control is also evident in the vicinity of Marshall and, in part at least, along the north fork of Andreafski River.

The region considered in this report lies wholly within the Yukon drainage basin, but the wide, flat, lake-dotted delta between the Yukon and the Kuskokwim, opposite and below Russian Mission, has so little relief that the watershed between the two rivers is difficult of location. So far as could be ascertained, there are few places, except near the coast, that rise even so high as 100 feet above either of the rivers. At high stages of water much of this lowland is inundated. During the spring of 1916 the small steamer *Tana* left the Yukon through a slough near Pilot station and, entering the Kashunuk River, reached Bering Sea through Hazen Bay. Essentially similar conditions are to be found in the delta of the Innoko. At high water this river may be reached through any one of several mouths, from a point several miles above Anvik to the last slough, about 11 miles below Paimiut. Other tributaries of the Yukon enter that river from the west and north after passing through considerable delta areas, modified by overflow from the Yukon and truncation of their fronts by the larger river. Bonasila, Koserefski, Kuyukutuk, and Chyilnuk rivers and many of the smaller creeks enter the Yukon through sloughs. Lakes are characteristic of the flood plains of some of these streams throughout their lower reaches and were especially noted in the broad depression occupied by Kuyukutuk and Chvilnuk rivers, which resembles in this regard the region between the Yukon and Kuskokwim.

CLIMATE.

The climate of the Anvik-Andreafski region is intermediate in character between that of the upper Yukon and the coastal region from Norton Sound to Bristol Bay. The proximity of Bering Sea has a stabilizing influence, so that the summer temperatures are not so high, nor as a rule are the winter temperatures so low as those of the upper Yukon, although north winds may occasionally bring about similar conditions in the two areas. From the records the precipitation appears to be greater in this region than at coast points and almost double that of points in the upper Yukon Valley. In any two consecutive seasons there is likely to be considerable difference in the amount of rainfall and in the times when precipitation takes place, but normally the greatest precipitation occurs after the middle of July. In 1916 records were kept from June 15 to September 10, inclusive. In the 40 days from June 15 to July 25 there was some precipitation on 21 days, or 52 per cent. From July 25 to September 10 there was some precipitation on 35 days of the 48, or 73 per cent.

Records of the time of opening and closing of the Yukon at Holy Cross have been kept for a considerable number of years, and there is probably under normal conditions very little difference between the dates at this point and others as far down the Yukon as Andreafski. These dates may be summarized as follows:

Ice began running in spring between April 29 and June 1.
River clear of ice between May 21 and June 3.
Ice began to form in autumn between October 5 and October 16.
River closed between October 19 and November 3.

It was noted that the rains are usually brought by southerly winds and that northerly winds prevail during periods of fair weather. The southerly winds are frequently of such force as to impede navigation seriously, as the steamboats are likely to be driven aground on some of the numerous bars of the river, and the seas caused by the wind make navigation dangerous for any small boat except a dory or one of the skin boats of the natives. The activity of the wind as an erosive agent was observed many times on the sand bars in the river, for as soon as the surface became dry it would drift before the wind and pile up in small irregular hummocks or dunes. Cross sections of dunes thus formed were exposed here and there in the cut banks of the Yukon.

VEGETATION.

Within the area crossed by the expedition of 1916 the conditions affecting vegetal growth are so diverse that a corresponding diversity of plant types is reasonably to be expected. In the vicinity of Anvik the lowlands are well timbered, although an approach to the tundra conditions found below Andreafski is presaged by the lowering of timber line compared with upper river points. In the vicinity of Anvik timber line is about 600 to 800 feet above the river; in favorable localities, such as sheltered, well-drained valleys, it extends somewhat higher. No spruce was seen growing on the Yukon below Andreafski, but scattered stumps of spruce and an occasional straggling birch indicate a former scanty growth of these trees to elevations from 100 to 200 feet above Andreafski River. From the hills back of Andreafski small patches of spruce may be seen scattered through the flat in the cottonwood and willow thickets extending along the Yukon above this point. The best growths of spruce are found along gullies, on slight eminences in the lowlands, or near the banks of streams. Farther back from the smaller streams in the lowlands, where drainage is poor, the growth is usually scattered and stunted. Wherever spruce is found on well-drained hill slopes birch generally occurs also, together with small-leafed poplar or quaking aspen. Extensive growths of these trees are apparently less common than in the Tanana basin. On Anvik and Bonasila rivers the birch bark is used by the natives in making their canoes. Tamarack grows in open groves in the more boggy places along the Anvik and Bonasila and was seen occasionally along the Yukon.

Throughout the lower-lying portions of the area cottonwood and several species of willow constitute the most abundant element of the forests. Some of the bars that have barely emerged from the river are covered with a dense growth of willows a few inches high. Alders are found at considerably higher elevations than any timber trees. They cover the slopes, in places occurring almost at the crests of the hills or ridges, where some protection is afforded by the depressions in the headward portions of the streams.

Grasses are surprisingly plentiful in variety and amount everywhere in the area, so that horse feed could easily be obtained for outfits traveling by pack train. This was especially true along the tributaries of the Yukon. On the Stuyahok there are many beautiful open parks containing luxuriant growths of grass, and at almost every point where a stop was made there was an abundance of forage. On the hilltops and most of the slopes a large part of the vegetal covering consists of mosses and lichens, but there is still a considerable amount of horse feed to be found even here. On the river bars there is usually an abundance of the variety of *Equisetum* called mare's-tail, and occasionally the pea vine is found.

When the party left the field (September 7) there had been no frosts of sufficient severity to destroy the nourishing qualities of the grasses, but the season of 1916 was probably exceptional in this respect, and killing frosts may ordinarily be expected early in September.

Fairly extensive agricultural operations have been carried on for a number of years by the mission at Holy Cross. The native grasses in natural meadows on the flood plain of the Yukon below the mission are cut and cured for forage or are utilized as pasture. A considerable variety of vegetables are grown for private use. Any surplus is sold and finds a ready market along the river. At Anvik some gardening is done, and several varieties of vegetables mature. The season without frost appears to be slightly longer here than farther up the Yukon.

Along the lower course of the Anvik are grass-covered areas almost wholly free from brush or timber. These natural meadows could doubtless be used for pasture or the grass cut for hay. Similar areas were seen on other streams, but there appear to be rather few along the Yukon.

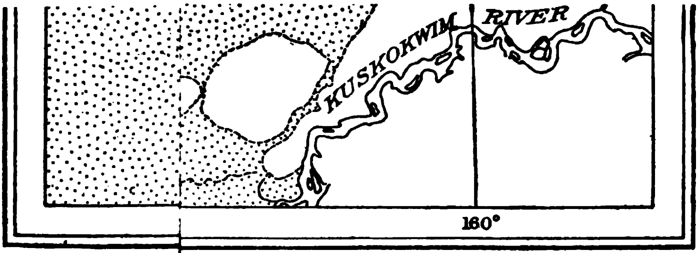
ANIMAL LIFE.

Animal life is abundant in the region, but there is little large game. Though only one small black bear was seen, the tracks were fairly common along the sand bars. Brown bear are reported. Neither caribou nor moose were seen, and it is said that there are none in this part of Alaska. Their former presence in great numbers is recorded by the earlier explorers, and on some of the ridges their trails are still visible. Domesticated reindeer are herded in the southern part of the area, and small bands are pastured near Marshall and Andreafski.

Of smaller animals a few rabbits and an occasional fox were seen. Fox tracks were very frequently observed along the river bars, where the foxes had been stalking aquatic birds. Beaver dams and houses were seen on the Stuyahok, and there was also evidence of the presence of ermine, mink, marten, and muskrats on this and other streams. To judge from their tracks porcupines are fairly common. The red-backed mouse was frequently observed.

Ducks were seen almost constantly on the streams tributary to the Yukon. Geese were abundant on the Stuyahok and lower Bonasila, and in the fall they were seen in flocks of hundreds on the Yukon and Andreafski. Large flocks of ducks were also seen on the Andreafski, as well as smaller flocks of swans and cranes.

On clear-water streams having a good current grayling were taken with a fly, and no difficulty was experienced in getting as many as were desired. Occasionally a trout was caught, but they seemed less


KUSKOKWIM RIVER
160°

numerous than the grayling. Fish wheels and fishtraps are used on the Yukon for catching salmon and whitefish. The salmon are smoked and dried or salted down to be eaten during the winter, by dogs as well as men. The whitefish are used largely as summer feed for the dogs. Trout, pike, and pickerel are also said to be taken by the fish wheels or in nets. Considerable quantities of fish of the various kinds are caught in large dip nets, which are handled with consummate skill by the natives. In winter whitefish are caught through holes in the ice, the natives using for bait an artificial minnow made of bone or ivory.

GEOLOGY.

In general the geology of the region is fairly simple, although faulting and a moderate amount of folding have complicated the structure somewhat, so that detailed mapping would be difficult. Difficulties of this kind are increased by the widespread occurrence of Quaternary sediments and residual rock débris, which obscure or completely conceal the distribution of the underlying rock units. The banks of the Yukon, however, present excellent sections and afford opportunity for stratigraphic studies.

A series of greenstone tuffs and flows with some intercalated sedimentary beds of upper Carboniferous age are the oldest rocks found. Their distribution is indicated on the accompanying map (Pl. XVI). Locally, as at Bareface Bluff, these rocks appear to be mainly sedimentary in origin. In the vicinity of Marshall they are much deformed and are almost wholly recrystallized, so that they are now epidote-hornblende schists. Their original composition was probably andesitic or basaltic.

Overlying the greenstones is a thick series of conglomerates, sandstones, and argillitic rocks of Cretaceous age. Locally, metamorphism has produced quartzites, slates, or, as near Marshall, sheared conglomerates. Although the Cretaceous sequence as a whole gives the impression of a succession of rather thin beds, some thick masses of sandstone and grit were seen in which no trace of bedding was apparent. A large proportion of the sandstones are feldspathic, and from the nature of the individual feldspar grains it is inferred that the greenstones were the source of a large amount of the material that makes up the Cretaceous rocks. In the rock on Andreafski River, however, the feldspars are much more acidic than those found in the greenstone and presumably came from soda granite or from dioritic rocks.

No evidence of the Tertiary age of any of the rocks seen was found, but it is possible that some early Tertiary beds may be included in areas mapped as Cretaceous.

Intrusive and extrusive igneous rocks of a number of types are found in this region. Soda granite and dioritic rocks occur in batholiths and dikes, which may belong to two periods of igneous activity—early Mesozoic and Tertiary. Accompanying the later of these intrusions were dacite and andesite dikes, flows, and tuffs, of which the dikes are known to intrude Cretaceous sediments.

At numerous places in the northern part of the area are basalt flows and tuffs, presumably of late Cretaceous or early Tertiary age. They are in part vesicular, in part amygdaloidal, and in part dense and containing little cavity space. At and west of Russian Mission are basalt dikes and flows which are thought to have been extravasated in late Tertiary or Quaternary time.

Sediments of Quaternary age are of widespread occurrence and include deposits of probable marine origin, as well as the products of stream alluviation. The marine sediments appear in the high cut banks of silt, sand, and gravel along the Yukon and its tributaries and are not everywhere readily distinguishable from the later stream deposits. In addition to the various types of sediments, vegetation and the débris due to the weathering of the underlying rock form a mantle that conceals the nature and relations of the older formations.

MINERAL RESOURCES.

HISTORY OF MINING DEVELOPMENT.

Gold has long been known to occur on Anvik River in amounts sufficient to stimulate prospecting, but no rich deposits have yet been found. Its presence on many other streams in the area has also been known to some of the prospectors of the region. Wilson Creek had received some attention, but it was not until July 15, 1913, that gold was discovered on this stream by E. L. Mack and Joe Mills. A stampede followed, and practically all the streams near by were covered with locations, Willow Creek among the number. It was not until June of the following year, however, that gold was discovered on this stream by W. C. Blanker, Ben Blanker, and Robert Barr. Some quartz claims were located near the head of Willow Creek in August, 1914, by Tom Plunkett. Up to the beginning of 1916 the district had produced about $40,000.

To facilitate recording the Wade-Hampton district was established, with the recorder's office at Marshall. It is that part of the second judicial district south of a line drawn along the crest of the divide between Yukon River and Bering Sea, starting at a point between Pastol Bay and the Yukon and extending to the one hundred and sixty-first meridian. The boundary of the district follows the one hundred and sixty-first meridian to a point within 5 miles of the Kuskokwim, runs parallel to the Kuskokwim at a distance of 5 miles to the sixtieth degree of north latitude, and thence goes due west to Bering Sea and northward to the point of beginning. Islands adjacent to the Bering Sea coast are included within the district.

ECONOMIC FACTORS AFFECTING MINING.

Timber is fairly plentiful for such operations as have been conducted. On Elephant and Disappointment creeks fuel could be procured for a time from the bottoms of the valleys. Extensive operations, using steam power, would necessitate the hauling of wood from the valley of Wilson Creek. Alders are the only trees found on Willow Creek above claim No. 2 below Discovery; consequently all the fuel used for producing power is obtained from the gentle foot slope between Spruce Creek and the hills. This wood costs $5 a cord to cut, and by the time it is laid down at the mine plant ready to use there is an additional charge of $5 to $7 for labor and hauling.

Wages are about the same as at other interior Alaska points. Miners are paid $5 a day and board, and hoistmen, blacksmiths, and cooks receive $7 and board. Two shifts of eight hours are employed by the larger plants; the smaller plants work but one shift. Employment was given to everyone who wished to work when there was a full sluice head of water. Natives are employed around the camp but do no mining. They are paid $2 to $3 a day.

The camp on Willow Creek is easily accessible. About 3 miles from the camp Spruce Creek flows into small lake which empties through a slough into the Yukon, rising and falling with it. Supplies may be brought to the landing on the lake by gasoline boats or in scows, and one of the smaller steamboats also brought a barge load of lumber up to the lake. The freight rate from Marshall to the landing, about 8 miles by boat, is $15 a ton. From the landing the rate is $30 a ton to the lower claims on the creek and $40 a ton to points as far up as claim No. 5 above. The winter rate will probably be much lower. The rate from Seattle to Marshall by way of St. Michael is $45.50 a ton on general merchandise.

In 1916, on account of traffic conditions, there was a scarcity of some commodities at Marshall. The following prices per pound were paid for staples on the creek:

Flour	$0.10
Bacon	.37
Coffee	.75
Tea	1.00
Beans	.12
Rice	.12½
Sugar	$0.13½
Butter	.67½
Reindeer meat	.25 to .30
Beef	.45 to .50
Potatoes	.07½

Lumber was difficult to obtain until a barge load was brought down from Ruby. This sold at $80 per thousand feet at the lake.

GOLD PLACERS.

WILSON CREEK.

Until the summer of 1916 most of the mining in the Marshall district had been done on Wilson Creek and its tributaries. In the spring of 1916 a small dump was taken out on Elephant Creek, and early in the summer considerable ground was worked at the mouth of Disappointment Creek. At the time of the writer's visit, about the middle of August, there was no one working in the Wilson Creek basin.

Mining had been done by underground methods on claim "No. 5 above" on Elephant Creek, although the ground is comparatively shallow. It is understood that an hydraulic installation is to be made, the water to be obtained from the headwaters of this stream. The ground on claims above and below No. 5 will be stripped and mined by hydraulic methods.

The workings on Wilson and Disappointment creeks have been confined to about two claims at the mouth of the latter, over a maximum width of about 300 feet. The gravels containing gold in quantities sufficient to justify mining appear to have been irregularly distributed, as work was done at several spots separated from one another by unworked ground. Open-cut methods had been employed. The deposits are shallow, apparently not over 10 or 12 feet deep to bedrock. The upper 2 to 3 feet of this material is composed of soil and vegetable matter and, with some of the underlying gravel, was stripped off by ground sluicing. The lower stratum of gravel containing the gold was shoveled into sluice boxes. It is said that holes sunk at the mouth of Disappointment Creek failed to reach bedrock at a depth of 35 feet. They were then abandoned on account of water coming in. No mining has been done in the deeper gravels of the main stream.

The principal mineral found in the concentrates is hematite, probably coming from what is believed to be the weathered outcrop of a pyritized sedimentary bed farther up the creek. In addition to the hematite there is a small amount of magnetite, which occurs in characteristic octahedra.

The bedrock is sedimentary in origin. It was not seen in the creek bed, but slate and conglomerate, together with fine grit, appear along the south bank of Wilson Creek just above Disappointment Creek, and these rocks, together with some dark-gray chert, make up most of the gravels. Some pebbles are derived from dikes that cut the sedimentary rocks and from the igneous rocks at the head of the creek. The gravels are mostly small and well-rounded pebbles, 8 inches being about the average diameter of the largest cobbles seen.

The finer material of the gravels is partly ferruginous, and, although it disintegrates readily in the sluice boxes, on exposure to the air it hardens and cements the larger pebbles into a conglomerate.

WILLOW CREEK.

Willow Creek heads against Disappointment Creek, and the divide rises 700 or 800 feet above the claims on which most of the mining has been done. Mining has been confined to the west fork of the creek and to the claims from No. 2 below to No. 5 above Discovery; the latter claim covers some ground on the western one of the small forks near the head of this stream. Some prospecting has been done on No. 6 above and on other claims below No. 2 below Discovery, but at the time of visit development had not progressed sufficiently to warrant the undertaking of mining operations.

Two small plants were operating on "No. 5 above," shoveling into sluice boxes. Prospecting was being done on Nos. 3 and 4 above Discovery, and it appears probable that some mining will be done on these claims in 1917. Power plants were working on "No. 2 above," the upper half of "No. 1 above," and the upper half of Discovery claim. On Nos. 1 and 2 above Discovery the auriferous gravel is wheeled in barrows to a bucket and then hoisted to the lines of sluice boxes, which have been placed on the side of the hill. A portion of the stripping is done in the same way, but some of the overburden is removed by sluicing.

The plant operating on the upper half of Discovery claim will also work the lower half of "No. 1 above." As these claims lie below the steep-walled portion of the valley, the line of sluice boxes is mounted on trestles to get the necessary grade and dump room for tailings. A novel feature at this property is that both stripping and hoisting are done by a slack-line scraper, a modification of the drag-line scraper used in other Alaska mining districts. The bucket has a capacity of 1½ cubic yards. On account of the large size and angularity of the boulders and the extremely uneven and blocky character of the bedrock, some difficulties have been experienced with this equipment. It appears likely that the bedrock will have to be cleaned by hand, as it is on other properties. The conditions of operation on Willow Creek for a scraper of this type are probably as difficult as will be found anywhere else, and its successful operation here would merit an investigation into the possibilities of its economical use at other Alaskan camps. On Disappointment Creek the rounded and smaller gravels appear to offer more favorable conditions for such an installation than are afforded by any of the placer ground on Willow Creek.

During 1915 the most extensive mining operations on this creek were on the lower half of Discovery claim. Operations were continued in 1916, and one shift of men was employed shoveling into the sluice boxes. The sluice-box arrangement differs from that on other properties, and a greater effort is made to save the fine gold. The upper four boxes, into which the gravel is shoveled, have false bottoms, in which are 2-inch holes spaced 4 to 6 inches on centers. Below these in the line is a box containing Hungarian riffles, with a 6-inch drop to a mud box. The mud box, like the three sluice boxes that follow it, has pole riffles of the usual type. At the other properties on the creek all the sluice boxes carry pole riffles, made either of local spruce poles or, when it is obtainable, of sawed 2 by 2 inch lumber. The sawed riffles are generally faced with 2-inch strap iron.

Mining was done on the upper end of the Bumblebee claim early in the summer, and a small area of ground was worked out. Operations were then shifted to the claim below, and preparations were made for more extensive mining. A sluiceway had been excavated 8 or 10 feet to bedrock, and boxes were being put in on August 27, when the writer left the creek. The contemplated operations include the sluicing of both the overburden and the auriferous gravels from "No. 2 below" through this line of boxes.

On account of the small drainage basin of the creek, the water supply for the claims lying above Discovery is likely to be somewhat scanty unless there are frequent rains. By the time it reaches Discovery claim even this scanty supply has been somewhat lessened. The operators on Discovery claim have diverted the water from the East Fork of Willow Creek and so increased the amount available for this claim and those below it. A ditch from Slope Creek was constructed late in the summer to furnish an additional supply for the mining operations on "No. 2 below."

About even with Discovery claim there is a distinct change in the topography, the front of the range of hills occurring at about this point. Below Discovery claim a wide, coalescing apron slopes gently down to Spruce Creek and the Yukon. Above this break Willow Creek has a V-shaped valley with rather steeply sloping walls; below it the stream has intrenched itself but little in the frontal apron and flows across it at a gradient lower than where it is confined within the valley. There appears to be a suggestion of a beach line between altitudes of 500 and 600 feet, but little evidence has been found at this locality to confirm the suggestion. The widening and somewhat irregular distribution of the auriferous gravels below Discovery claim may be due in part to beach concentration and in part to the changing of the channel of the stream before it had become intrenched in its present course.

The depth to bedrock ranges from about 6 to 16 feet. On "No. 1 above" it is from 12 to 16 feet. The upper half consists of soil and angular rock fragments with comparatively little rounded gravel. This is stripped off before the lower layers are mined. Gold is found both above and below a clay seam lying about 2 feet from bedrock, some of the coarsest gold being found above it. The bedrock is extremely rough and blocky and just above it there are a considerable number of large angular boulders. Part of these are talus boulders from the valley slopes, and part represent frost-heaved material from the greenstone bedrock. On the lower claims there appear to be more rounded gravels, but the bedrock is similar in character to that on the upper portion of the creek.

The gold is somewhat rough, and some of it appears rather porous. Over half of it is too coarse to pass through an 8-mesh screen. Nuggets valued at $5 to $10 are not uncommon in the clean-ups, but those worth over $20 are few. The very fine gold saved constitutes only a very small percentage of the clean-ups. It is believed that the installation of devices for saving the fine gold would be warranted, as some of the fine gold already saved is flaky and light and it is quite possible that a greater proportion of this light gold goes through the boxes than is saved in them. Few assays of the Willow Creek gold are available. One of these is said to have given a value of $18.30 an ounce. The gold passes current at $17 an ounce.

Magnetite is one of the most common minerals associated with the gold in the clean-ups. Ilmenite occurs in small amounts. Although pyrite may be seen occasionally in the greenstone near the head of the creek, little or none is found in the concentrates, oxidation having converted it to hematite.

GOLD LODES.

Since the development of the placers in the vicinity of Marshall the hills have been prospected to find the lodes from which the placer gold has been derived. A number of lode claims have been staked in the Kuyukutuk basin, on the north side of the ridge extending eastward from Pilcher Mountain. Little development work is reported as having been done on these claims, and they were not visited. Free-milling gold is reported from quartz veins near the head of Edgar Creek, and claims have been staked there. A number of quartz veins were seen along the crest of the divide between Wilson and Spruce creeks. Claims have been staked to cover most of these veins, but no evidence was seen of work having been done upon any of them except on the east side of Willow Creek near its head.

The group of claims known as the Arnold lode was staked August 8, 1914, by Tom Plunkett. The development work consists entirely of open cuts made with a view to determining the size and continuity of the veins, of which a number are exposed. One of the lower veins has been traced along its strike for over 100 feet by a series of trenches 2 to 6 feet deep, through the talus and slide of the hillside. The vein is from 6 inches to a foot in width. It shows free gold in places. Farther up on the slope a cut has been dug about 30 feet into the hill, so that a face 12 or 15 feet in height and 3 to 6 feet in width is exposed. In this face is shown a quartz vein whose width ranges from 4 to 8 inches. The minerals in the vein include calcite, pyrite, galena, molybdenite, and free gold. In places the pyrite is oxidized, and the quartz is stained with iron oxides. There are numerous cavities formed by the removal of pyrite and calcite. In some of these cavities small crystals of glassy quartz may be seen, together with scattered rosettes of calcite crystals. Some of the dirt from the bottom of the open cut was panned. In addition to the vein minerals mentioned above the concentrates from panning included small amounts of wulfenite, the yellow to orange-colored molybdate of lead, and anglesite, the white sulphate of lead. Magnetite and the oxides derived from the alteration of iron pryrite are also present in considerable amounts. Their source is the greenstone country rock, the hanging wall in places showing strong pyritization. Veins near by show a small amount of chalcopyrite accompanied by the characteristic green stain produced by its oxidation.

COAL.

The presence of coal on Anvik River has long been known and is mentioned by Collier.[1] The coal seems to have been used to a slight extent by the natives, who formerly employed it in the manufacture of a black pigment. A small amount has also been used for blacksmith coal at Anvik, but so far as known no other utilization has been attempted.

The following information regarding these deposits was obtained from Mr. F. H. Kruger, a merchant and prospector at Anvik. The coal seams crop out about 45 miles above the mouth of Yellow River, or over 100 miles by water from the Yukon. The air-line distance to the nearest point on the Yukon is probably about 25 or 30 miles. Anvik River cuts diagonally across the sedimentary series, which is made up of sandstone, shale, and coal beds. These beds appear for a distance of about 5 miles along the course of the stream. Both up and down stream from the sedimentary series are rocks of igneous origin. Within the series coal seams appear for nearly a mile along the river. Most of the outcrops are on the east bank. One seam has a thickness of about 10 feet and several are 2 feet thick.

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[1] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, p. 58, 1903.

Transportation to the Yukon would entail a high expense, as only small poling boats could be used except at high stages, when small scows and power boats might be utilized. Transportation overland would prove feasible only if the local market were sufficient to warrant the construction of a road, after exploration and development work had proved the extent and quality of the coal.

Coal seams of varying thicknesses will doubtless be found elsewhere in the areas of Cretaceous rocks. Many fragments of weathered coal were found in the high gravel bank on the east side of Stuyahok River, about 45 miles from its mouth. It is likely that these fragments have not been carried for any great distance and that careful prospecting would reveal the seams from which they were derived. Like those on the Anvik, these beds when found would probably be of local value only, unless they were of considerable extent and of such a quality as would permit them to compete with other fuels.

At Marshall it was learned that coal occurs on one of the creeks that flows into a slough of the Yukon, about 20 miles above Marshall. No other information concerning this deposit was obtainable.

A narrow band of bituminous shale in the vicinity of the old fort at Andreafski is mentioned by Dall.[1] The Russians attempted to utilize this shale for fuel, but it was too impure to burn well, and the attempt was abandoned. This locality is a few miles down the Yukon from the mouth of Andreafski River, where field work was terminated in 1916, and it was not visited by the writer.

MINERAL SPRINGS.

About 7 miles east of Marshall and half a mile from the Willow Creek landing are what are known locally as the Soda Springs. Analyses show that the mineral content of the waters from these springs is largely iron and lime carbonates. Free carbon dioxide is constantly being liberated and bubbles up intermittently in almost all the pools and springs of this group. Some have built up considerable cones, 4 to 6 feet high and 10 to 20 feet in diameter at the base. The material in these cones consists of lime carbonate and yellow and red iron oxides. At the northern edge of the group is an extensive area covered with granular precipitated oxides of iron, with some lime carbonate, which is rather loose and incoherent, much resembling gas-house cinders. It has been built up sufficiently to afford a solid footing, in contrast with the soft, spongy moss-covered areas adjoining. Very little vegetation grows on the sinter.

Between the main group of springs and the landing are a number of pools of water which in part may represent the overflow from the springs above and in part may be the basins of springs of a comparatively small flow. The deposits in the vicinity of these pools are chiefly lime carbonate and are conspicuous for their white color and scanty growth of vegetation.

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[1] Dall, W. H., and Harris, G. D., Correlation papers, Neocene: U. S. Geol. Survey Bull. 84, p. 247, 1892.

The springs are at the base of the south frontal slope of the range of hills between Spruce and Wilson creeks. A mantle of vegetation and unconsolidated material so completely covers the surface that it is impossible to determine the nature of the underlying bedrock. It appears likely that the springs occur near the contact of the Quaternary lavas and the undifferentiated metamorphic rocks which make up the ridge to the north. Other springs of essentially similar character are reported as occurring about 12 miles to the east, where the topographic situation and geologic conditions are much the same as at this locality.

ANTIMONY.

No deposits of antimony are known within the areas visited, but at Paimiut it was reported that antimony occurs in the group of hills between the Yukon and the Kuskokwim, near the latter.

MINERALIZATION.

Data regarding the mineralization in this region are not sufficiently complete to warrant positive statements regarding the source of the gold, but some inferences concerning it can be drawn. Wherever gold has been found there are also dikes of soda granite or porphyritic dacite, many of them of considerable width, and it is believed that the mineralization was consequent upon their intrusion of both the sedimentary and igneous rocks. The dacite is similar in chemical composition to the soda granite and differs only in possessing a somewhat finer groundmass and a porphyritic texture. It represents offshoots from the larger igneous masses or was derived from the same sodic granite magma. Both the larger granite masses and the dacite dikes appear to have been concerned in the mineralization. The quartz veining that followed was related to the intrusives, and much of the gold occurs in the vein quartz, but impregnation of the wall rock has also taken place. Besides the gold, the sulphides of iron, lead, molybdenum, and copper occur in the veins and mineralized wall rock. These minerals have not been found in the soda granite or dacite but doubtless were due to their intrusion.

SUGGESTIONS FOR PROSPECTING.

As the mineralization was attendant upon the soda granite and the porphyritic dacite, it follows that streams coming from areas where these rocks appear afford the most attractive field for prospecting. Rock exposures are few but may usually be found along the crests of the ridges or here and there along minor streams, but the nature of the gravel along bars will afford an equally reliable indication of the nature of the rocks farther upstream. Vein quartz or pebbles of light-colored granitic or porphyritic igneous rock should be noted. These are not necessarily accompanied by gold, but on the other hand all the gold that has been found in this region occurs under conditions which indicate its relation to these intrusives.

Along the upper courses of the streams the valleys are for the most part comparatively narrow and the depth to bedrock slight, making crosscutting of the channel fairly easy. In the lower reaches, however, the width is greater, in places being several miles, and the valley fill is of unknown depth. Moreover the streams may have shifted their courses since placers were possibly concentrated. It appears, therefore, that the prospecting of these broad deposits would be both difficult and uncertain of profitable results.

LODE DEPOSITS NEAR THE NENANA COAL FIELD.

By R. M. Overbeck.

INTRODUCTION.

The lode prospects described in this report were visited during the summer of 1916 by G. C. Martin and party in the course of a rather detailed examination of the coal-bearing areas of the Nenana coal field. The part of the field that was investigated extends from Nenana River eastward about 18 miles and from Healy Creek northward about 22 miles and lies approximately within the limits of 148° 25′–149° 01′ west longitude and 63° 54′–64° 10′ north latitude. (See accompanying map, Pl. XVII.) The mouth of Hoseanna Creek is about 50 miles south of the new town of Nenana, at the junction of Nenana and Tanana rivers, and about 70 miles on a direct line southwest of Fairbanks. The Government railroad, now under construction, is projected to cross to the west side of Nenana River about 4 miles above the mouth of Moose Creek and 8½ miles below the mouth of Hoseanna Creek.

No lode mining has been done in the area outlined, and prospecting has not been extensive. Gold is the principal mineral sought. A gold quartz claim was staked several years ago on McCuen Gulch, in the SE. ¼ sec. 1, T. 10 S., R. 5 W. A mineralized zone that apparently is gold bearing is reported from Fourth of July Creek about half a mile above its mouth. A stibnite lode was located a few years ago on Cody Creek in the SE. ¼ sec. 8, T. 11 S., R. 7 W., and in 1916 was relocated. In 1915 and 1916 prospecting became more active, owing to the finding in Eva Creek of float rock that was heavily mineralized with arsenopyrite, bismuth, and bismuthinite and that was reported to carry gold. Search for the source of this rock led to the discovery of several mineralized zones, and about 20 locations (claims and tunnel sites) were made on Eva Creek and on Moose Creek.

The purpose of this report is to give a few facts that may be helpful to the prospector concerning metallization in the region, for the coming of the railroad and the opening of the coal fields will doubtless stimulate the search for lode deposits. Unfortunately, however, prospecting has not been extensive enough to furnish much information about the occurrence of ore bodies.

The area described in this paper lies in the northern foothill belt of the Alaska Range. This belt, which is about 25 miles wide where Nenana River cuts through it, is bounded on the north by the Tanana Flats. More or less discontinuous ridges, separated from one another by rather broad, flat structural valleys that run parallel to the main range, make up the foothill belt. Schists and igneous rocks form the more rugged ridges, and partly consolidated clays, sands, and gravels form the valleys and some of the high rounded hills. Jumbo Dome, the highest hill in the region, has an elevation of 4,500 feet, and the Nenana near the mouth of Moose Creek an elevation of 1,000 feet—a total difference in relief of 3,500 feet. The streams that drain the region flow northward into the Tanana and westward into the Nenana. The chief northward-flowing stream is the Totatlanika, which with its branches drains about two-thirds of the area investigated. Healy, Hoseanna, Walker, and Moose creeks are westward-flowing streams. Totatlanika Creek and its tributary, California Creek, run in canyons where they cut through the schist ridges, and Hoseanna Creek has a narrow, steep-sided valley deeply incised in the partly consolidated clays, sands, and gravels of the coal-bearing formation. The streams near the lode prospects are small and furnish barely enough water for small placer workings. The annual precipitation in the region is small, being at Fairbanks about 11.5 inches. Timber line lies about 2,100 feet above sea level. The trees (spruce and cottonwood) grow chiefly along the stream courses and are mostly small and of little use for construction. The Tanana Flats, however, are fairly well covered with spruce and should supply some mine timber. Lignite is abundant in the coal fields. In 1916 a wagon road ran from Nenana through the flats almost to the foothills, and thence a good horse trail follows the gravel ridges to Hoseanna Creek. Horse feed grows profusely.

GEOLOGY.

The main geologic features of the region are known through the investigations of Brooks and Prindle (1902),[1] Prindle (1906),[1] and Capps (1910).[2] As the work of 1916 was limited practically to the areas in which the coal-bearing rocks crop out, a description of the rocks of the district as a whole is abstracted from Capps's report.

> The oldest rocks of the region, the Birch Creek schist, form the greater part of the high mountains on the north slope of the Alaska Range. They comprise a great series of metamorphosed sediments, which now appear as quartz and mica schists and phyllites, with schistose and micaceous quartzite. * * *
> No evidence has been found in the Bonnifield region which would determine the age of this schist series, but from its relations with younger fossil-bearing

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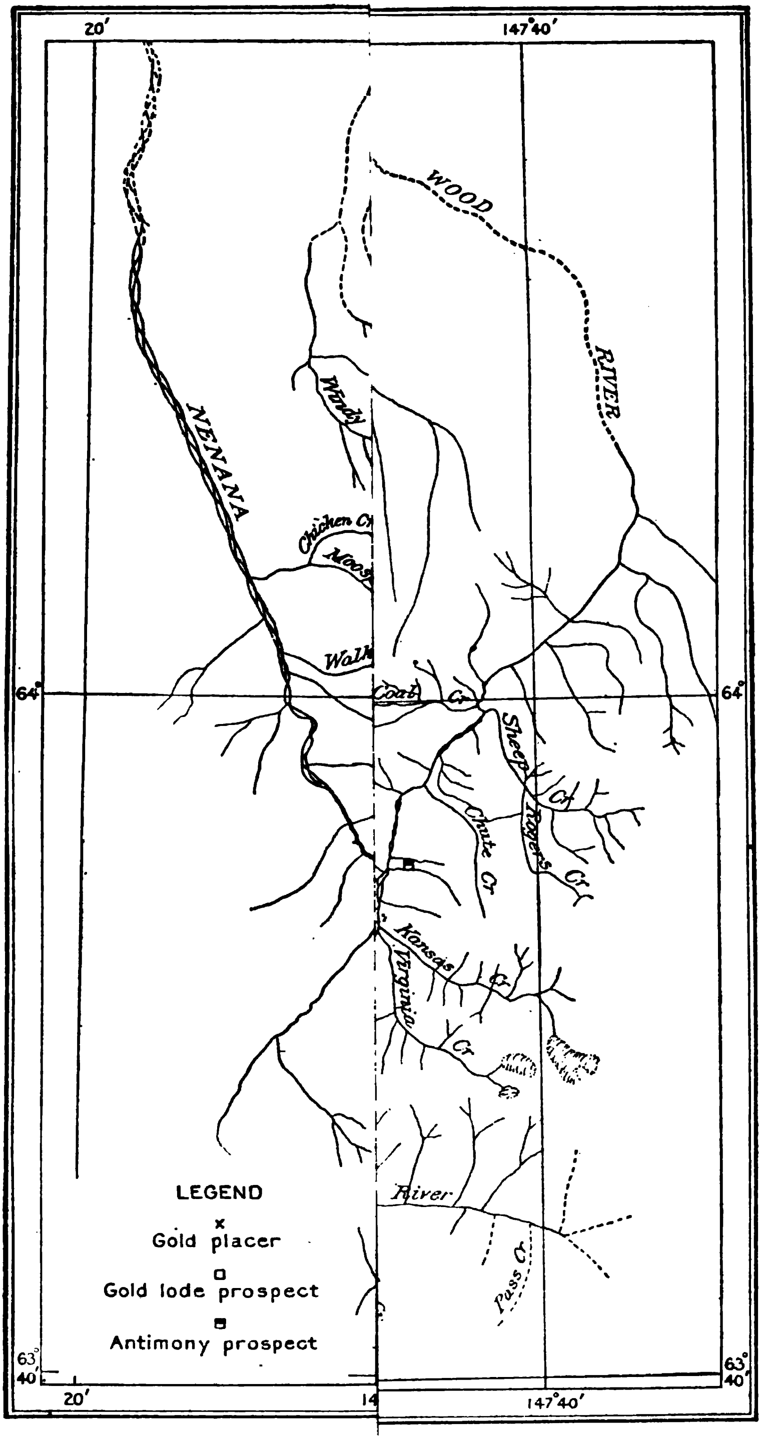
[1] Brooks, A. H., and Prindle, L. M., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, 1911.

[2] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, 1912.


20′
147°40′
WOOD RIVER
NENANA
Windy
Chicken Cr
Moose
Walk
Coal Cr
64°
64°
Sheep Cr
Rogers Cr
Chute Cr
Kansas Cr
Virginia Cr
River
Pass Cr
LEGEND
×
Gold placer
□
Gold lode prospect
▣
Antimony prospect
63° 40′
63° 40′
20′
14
147°40′

MAP SH FIELD.

formations in other places it has been provisionally determined to be of pre-Ordovician age.

Next younger than the Birch Creek schist and forming the foothill ranges to the north of the main mountain range is a thick series of quartz-feldspar rocks, to which the name Totatlanika schist is here applied, from typical exposures along the creek of that name. These are for the most part metamorphosed igneous rocks but include some infolded beds of sedimentary origin. * * * The whole series was * * * folded, faulted, and greatly metamorphosed. Near Nenana River the schists appear at the surface across a belt 18 miles wide, although in places they are covered by younger deposits. * * * The quartz-feldspar schists and the associated beds of sedimentary origin are provisionally assigned to the Devonian or Silurian.

The period of metamorphism was succeeded by a long period of time during which the area here considered stood above the sea and was denuded to a surface of slight relief. Of this erosion period no record is left in the deposits of the Bonnifield region. The next younger beds are of lower Tertiary age (Eocene) and consist of loosely cemented conglomerates, sands, clays or shales, and lignitic coal occupying basins formed between ridges of the older schists. * * * The lower Tertiary beds, although locally folded and faulted, present a young appearance as compared with the schists on which they lie.

After the coal-bearing series was deposited, the uplift of the Alaska Range began, and the folding of the rocks formed a number of depressed basins in which the lower Tertiary beds were preserved. Between these basins and in the Alaska Range proper the uplift exposed the loosely cemented materials to erosion, and they were removed from much of the area which they had formerly covered.

A rather thick series of gently folded clays, sands, and gravels, which are younger than the coal-bearing rocks and which may be of Pleistocene age, rest on the schists and on the coal-bearing formation at many places. These deposits are the Nenana gravel described by Capps.[1] Bench gravels and alluvial gravels along the courses of the present streams are the youngest rocks of the region.

Igneous rocks later than those which make up the Totatlanika schist are abundant. They occur as intrusive bodies that cut the schist and as flows. Quartz porphyry, dacite, hornblende andesite, and andesite are the types represented.

The unaltered sedimentary rocks of the region, although they contain coal beds that would be highly important as a source of fuel in the event of the development of lodes, have had no direct part in the formation of the lode deposits and so will not be further discussed.

The schists, which are sedimentary and igneous rocks that have changed their character under the action of great differential pressures, have been separated by Capps into two types—the Birch Creek schist, which consists chiefly of altered sedimentary rocks, and the Totatlanika schist, which consists of altered igneous rocks. The Birch Creek schist, which occupies but a small part of the region, is not associated there with lode occurrences, but much of the gold in the placers of Tanana Valley and in part of Yukon Valley is believed to be derived from it.

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[1] Capps, S. R., op. cit., p. 30.

The country rock of the prospects is the fine-grained dark carbonaceous phase of the Totatlanika schist. It is described by Capps[1] as follows:

> Associated with the altered igneous rocks, especially in the lower part of the series, are commonly to be found beds of carbonaceous shales and schists and some quartz conglomerate, which are certainly of sedimentary origin. * * * It is probable that the laying down of the sediments was interrupted at times by the extrusion of igneous rocks, so that they belong properly to the same time period. The beds of clastic origin are prominent only near the base of the Totatlanika schist.

Specimens of this schist from the lode prospects differ somewhat in appearance. The typical dark schist is nearly black, is fine grained, consists chiefly of quartz (?) and carbonaceous material, and is cut by numerous small stringers of quartz. Through the action of the weather the rock becomes soft and breaks into thin black leaves and plates. Other rocks contain much sericite and weather light yellow. These two types are probably altered sediments. Some of the light varieties, however, resemble altered rhyolites in texture, and hence may be of igneous origin. The dark schist, the weathered outcrops of which look much like coal, is found near all the prospects, and on a branch of California Creek a body of iron-mineralized rock was observed just beneath a belt of the black schist. Whether this phase of the schist is connected genetically with the lode deposits is not known, but the field association of black schist and prospects is at least suggestive, and the prospector in this region should search carefully for lode mineralization wherever he sees outcrops of black schist.

The igneous bodies near the prospects are dikes and rather small, irregularly shaped, intrusive masses, which cut the Totatlanika schist and project above it as spines, as walls, or as mounds of platy rock. All the intrusive rocks are of the same general type, but the great difference in amount of alteration in rock bodies closely associated in the field points to a difference in age. Unsheared and sheared dikes, for example, are found close together. An abundance of quartz and orthoclase occurs in the rocks of both the sheared and the unsheared masses. The sheared rock is dark and shows some banding. The bands are lines of small overlapping lenticular areas of quartz and feldspar, which alternate with lines of dark fine-grained sericitic material. The unsheared rock is light brown or light gray, does not show banding, and is characterized by the prominence of clear quartz grains, or phenocrysts, which are about one-thirtieth of an inch in diameter. Feldspar crystals of the same size as the quartz grains are also abundant but are not so noticeable as the quartz. The microscopic study of these rocks confirms the field determination of quartz porphyry. Phenocrysts of quartz and orthoclase are set in a fine-grained groundmass, which consists in the unsheared rocks of intimately intergrown quartz and orthoclase, and in the sheared rocks of crushed quartz and feldspar, sericite, and possibly chlorite and other alteration minerals.

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[1] Capps, S. R., op. cit., p. 25.

A genetic relation between the quartz porphyry—acidic intrusive rocks—and the lodes is suggested by their association in the field. This association is shown by the following examples. At the head of Moose Creek a number of the smaller acidic intrusive bodies are exposed, placer gold is found in the stream that cuts the bodies, and near them a stibnite lode and a gold claim have been located. Dikes occur on Eva Creek near the present lode prospects and above the placer workings. On Wilson Creek mineralized schist that carries a little gold was discovered near a large siliceous dike. A siliceous dike occurs near the gold lode prospect at the head of McCuen Gulch. Placers are being worked on Homestake Creek, which cuts a less siliceous rock, quartz diorite, but no lodes have been found near this stream. Little or no placer mining has been done on the streams that drain the slopes of Jumbo Dome, an intrusive body of hornblende andesite. The prospector should learn to recognize the siliceous intrusive bodies in the field and to realize that they probably played some part in the formation of the lodes.

As a result of the action of great forces the rocks of the region are faulted and folded and the older rocks have been converted to schists. The effect of rather recent movement is shown by the gentle folding and faulting of the Nenana gravel, which may be of Pleistocene age. Faults and fault zones may be important factors in the localization of ore deposits. They may, for example, afford passageways for mineralizing solutions. One of the prospects in the region was in a small shear zone in the schist, and all the present prospects are near a large fault that can be traced along Eva Creek, across the head of Moose Creek, and into Cody Creek. There seems, then, to be a relation in this region between the distribution of mineralization and faulting.

To summarize, the prospector should note the following facts about the occurrence of lode prospects in the district: (1) They are in the schist; (2) they are associated with the fine-grained dark schist; (3) they are near small acidic intrusive bodies; (4) they are related to faulting.

MINERALOGY.

None of the prospects have been opened up sufficiently to furnish specimens of the mineralized rock. The best material so far found occurs as float in Eva Creek, and consists chiefly of a mixture of arsenopyrite and quartz, in which are small amounts of native bismuth and bismuthinite and in some specimens a very little chalcopyrite and pyrite. The mineralized rock weathers rusty brown on the surface and its crevices and cracks are lined with green, yellow, and gray coatings that are probably alteration products of the arsenical minerals. Crushed specimens of these rocks are reported to yield gold when panned, and assays of hand specimens show the presence of some gold. Crystals of gold were obtained from the weathered rock of one of the prospects.

Arsenopyrite (an iron-arsenic-sulphur compound), the most abundant metallic mineral present, is not valuable as an ore mineral, but it may be useful to the prospector as an indication that metallization has taken place, as in this and neighboring regions gold is found in places associated with arsenopyrite. The mineral is recognized easily by its tin-white color, metallic luster, and hardness. (It will scratch the blade of a pocket knife.) Arsenopyrite is a very common mineral and has little economic importance. "Arsenic" (arsenic trioxide), which is extensively used in the manufacture of glass and of insecticides, is obtained in this country as a by-product of the smelting of ores rich in arsenical minerals.

Native bismuth and bismuthinite are abundant in some specimens from Eva Creek, and they are reported from the other prospects in the vicinity. Native bismuth that has been exposed to the weather is recognized by its rather deep yellow tarnish. A fresh piece of bismuth has a high metallic luster and is gray but has a distinct pinkish tinge. The mineral is very soft and can easily be cut with a knife.

Bismuthinite (bismuth sulphide) is a soft lead-gray metallic mineral with a high luster. It differs from native bismuth in color; the native bismuth has a decided pinkish tinge, which the bismuthinite lacks. It is not so hard as arsenopyrite, which it resembles somewhat in color. Fine-grained bismuthinite may be difficult to distinguish from fine-grained stibnite.

The uses of bismuth are few. It finds its most extensive application as salts for medicinal purposes. Its low melting point makes it useful in the manufacture of fuses for electric wiring systems and of plugs in devices for protection against fire. Its use as a metal is restricted, owing to its extreme brittleness, although it has been used somewhat for type metal. Practically all the bismuth obtained in this country comes as a by-product from the smelting of ores rich in bismuth minerals. In 1915 about 44,000 pounds of metallic bismuth, valued at $108,000, was imported. It sold at $2.50 to $3.50 a pound. Ores containing less than 10 per cent of bismuth can not be sold in this country at the present time, and the demand for bismuth ores is so small that the rates per ton of ore would be very low. It is to be hoped, however, that a demand will spring up and that much bismuth ore now on the dump heap may some day be valuable.

The antimony ore from the Rambler lode, on Cody Creek, is rather pure stibnite (antimony trisulphide) in a confused crystalline aggregate. A blackish tarnish covers exposed surfaces of the stibnite where weathering has not advanced far enough to form the usual yellow or gray crusts of decomposition minerals (stibiconite?). Stibnite is lead-gray, and has a metallic luster. It is very soft and can easily be scratched with a knife or even with a brass pin. Fine-grained stibnite can be distinguished only with difficulty from other fine-grained gray metallic minerals. Coarse-grained stibnite occurs in long, needle-like crystals, which are commonly bent and broken. The stibnite is distinguished from native bismuth by the pinkish hue of the freshly broken bismuth.

Antimony is used as an alloy in making type metal and babbitt metal, and in making shrapnel, and at present the demand for it is rather large. The price before the war was about 7 cents a pound; since then it has fluctuated widely and has reached 50 cents a pound. The present price (1917) ranges from 14 to 25 cents. About 833 short tons of antimony ore, carrying about 58 per cent of antimony, was shipped from Alaska in 1915 and sold in San Francisco at an average price of about $86 a ton.[1] About 1,460 tons of ore was mined and shipped during 1916. Most of this ore was from the Fairbanks district.

The accessory minerals, pyrite and chalcopyrite, occur in very minor amount. They are distinguished from practically all other metallic minerals by their yellow color. Pyrite, an iron sulphide, is typically very light brass-yellow; chalcopyrite, an iron-copper sulphide, is a rather deep greenish yellow. Pyrite and chalcopyrite are distinguished from one another by their difference in hardness; chalcopyrite can be scratched with a needle or with the point of a knife blade, whereas pyrite is harder than the knife blade and will scratch it. The yellow tarnish on native bismuth may cause it to be mistaken for chalcopyrite, but the true color of the bismuth is revealed when the tarnish is scratched away.

TYPE OF ORE BODY.

As prospecting and exploratory work have not been sufficiently extensive to disclose the actual condition and extent of the supposed ore bodies, their mode of occurrence can only be surmised. Most of the mineralization probably took place by deposition from solutions in shear zones or in fissures in the schist.

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[1] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, pp. 7–8, 1916.

GENESIS.

Concerning the genesis of the deposits only tentative generalizations can be made, for the facts necessary for definite conclusions are lacking. In the absence of conclusive field evidence, an attempt was made to get some light on the origin of the ores by an examination of thin sections and polished surfaces. Good specimens were lacking, but presumptive conclusions may be drawn from certain relations of the minerals. The ores were probably deposited from solutions rich in silica, partly as fissure fillings and partly, perhaps, by replacement of the schist, under conditions of rather high pressure and moderate temperature. No minerals that are formed characteristically under very high pressures and at high temperatures were found, nor is the quartz, which, with the possible exception of the quartz with the stibnite, is clear and in rather large crystals, of the fine-grained variety that at many places accompanies ores which are formed near the surface by heated solutions.

The sequence of crystallization of the ore minerals can be inferred in a general way from the polished sections. The first minerals deposited were quartz and arsenopyrite. Quartz began to crystallize apparently before the arsenopyrite and continued after all the arsenopyrite had come from solution. Examples of quartz cut by stringers of arsenopyrite, of quartz and arsenopyrite that show what Graton and McLaughlin[1] call "mutual boundaries," and of quartz stringers that surround and run between grains of arsenopyrite are abundant. A little orthoclase accompanies the quartz. Laths of sericite and of chlorite are associated with the arsenopyrite and with the bismuth minerals. Sericite occurs as an alteration product of the orthoclase.

The next metallic mineral to crystallize was apparently the accessory mineral chalcopyrite, which shows rather good crystal form, is definitely later than the quartz, is seemingly later than the arsenopyrite, and is definitely earlier than the bismuth minerals.

The native bismuth is apparently full of inclusions in the surface examined. The inclusions are so fine grained that they can not be surely identified, although the numerous laths present are probably chlorite or sericite. Bismuthinite is seemingly later than the native bismuth complex, which it crosses in stringers, and it is later than the laths (sericite or chlorite (?)), which it cuts and to some degree replaces. The laths, if correctly identified, are probably of hydrothermal origin.

Stibnite is not associated with the other metallic minerals in the sections examined, and consequently its relation to them is not known. Neither gold nor pyrite occurs in the polished surfaces.

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[1] Graton, L. C., and McLaughlin, D. H., Ore deposition and enrichment at Engels, Cal.: Econ. Geology, vol. 12, p. 17, 1917.

The order of crystallization of ore and gangue minerals seems to be as follows: Quartz and arsenopyrite, chalcopyrite, native bismuth, bismuthinite.

The source of the mineralizing solutions is the next point to be considered. Capps[1] makes the following statement about the origin of the lodes of the Bonnifield region (specifically of the Wood River basin):

> Associated with the schists of the main range, which have been correlated with the Birch Creek schist of the Fairbanks region, also cutting the quartz-feldspar schists to the north, are many intrusive granitic rocks, and there is some reason to believe that the mineralization of the schists may be due to these intrusions.

Brooks[2] says of the lodes of the Yukon-Tanana region as a whole that "there appears to be close genetic relation between the gold deposits and the granite intrusive rocks." In the Nenana region no large bodies of granite were found, although small granitic intrusive bodies are fairly abundant. These small granitic bodies, apparently to the exclusion of other igneous types, occur near all the present lode prospects and are probably related to them genetically. Field evidence does not show whether the deposits are related to the sheared or the unsheared granite intrusives or to both.

The geologic period of mineralization is not definitely known. The deposits are younger than the schists (referred provisionally to the Silurian or the Lower Devonian) in which they occur, and they are not found in the Tertiary rocks of the region. The granitic rocks with which metallization is probably associated are thought to belong to the "general period of intrusion, beginning possibly in late Paleozoic time and in some parts of the province extending through to the Upper Cretaceous, but having its maximum development late in the Jurassic."[3] If mineralization took place at a time when igneous activity was waning, the age of the deposits would be late Mesozoic. Prindle[4] says of the Fairbanks lodes that "the metallization probably occurred near the end of the Mesozoic era."

The seeming localization of some of the prospects along a fault that cuts Pleistocene (?) gravels does not necessarily indicate a Pleistocene age for the deposits. The region has been only slightly disturbed since the deposition of the early Tertiary coal-bearing rocks, and the fault may simply represent a zone of weakness which has persisted from Mesozoic time. This zone was probably not developed before very late Mesozoic time, for otherwise it would have lost its identity in the orogenic movements of the earlier Mesozoic. This fact, then, suggests that mineralization took place after early Mesozoic time. As metallization was found nowhere in the district in Tertiary rocks, and as the granitic rocks with which metallization is apparently genetically connected were nowhere seen to cut Tertiary rocks, the assumption, based on negative evidence, is made that metallization in the district took place in late Mesozoic time.

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[1] Capps, S. R., op. cit., pp. 52–53.

[2] Brooks, A. H., Geologic features of Alaskan metalliferous lodes: U. S. Geol. Survey Bull. 480, p. 68, 1911.

[3] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 52, 1911.

[4] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, p. 72, 1913.

Nothing definite could be learned about the age of the stibnite deposit. The fact that the stibnite occurs alone and was not found in association with the arsenopyrite and bismuth minerals suggests that it may belong to a different period of mineralization. Brooks[1] says that "the formation of stibnite lodes of Alaska seems to have taken place principally in Tertiary time."

A summary of the probable events connected with metallization in the region is as follows: The sulphides accompanied by gold were deposited from solutions in shear zones and possibly in fissures under conditions of rather high pressure and moderate temperatures; the solutions were derived from acidic magmas that formed the granitic dikes; arsenopyrite and quartz were deposited first and were followed by the bismuth minerals; metallization took place probably in late Mesozoic time, or, possibly, even in early Tertiary time.

PROSPECTS.

Almost no underground development work has been done on the claims in the district. A tunnel 35 feet long and a shaft 15 feet deep at the end of the tunnel were opened in the loose rock on the south side of Eva Creek, for the purpose of locating the source of the mineralized float rock in Eva Creek. Gold was panned from decomposed rock at the mouth of the tunnel, but the shaft was flooded before anything definite could be ascertained as to the existence of an ore body. On Eva Creek, about a quarter of a mile below the mouth of this tunnel, some of the decomposed material from a shear zone in the schist yielded some gold when panned. The decomposed material consisted of pyrite, arsenopyrite, chlorite, and scorodite (?). This shear zone strikes N. 15° E. and dips 75° S. On the north side of Eva Creek several shallow pits have been sunk into mineralized schist, but no information could be obtained concerning the extent or character of this mineralization. A hand specimen of oxidized schist carrying arsenopyrite and pyrite from a claim at the head of Moose Creek, in sec. 10, T. 10 S., R. 7 W., was found on assay to carry gold.

The stibnite claim, the Rambler lode, is on the north side of Cody Creek, a tributary of Moose Creek, in sec. 8, T. 10 S., R. 7 W. A shallow crosscut and two shafts, which were not accessible when the prospect was visited, are on the property. The crosscut in the hillside exposes two lenticular bodies of stibnite in a greatly oxidized fine-grained sericite schist. The two lenses are about 4 feet apart. The larger one strikes about N. 70° E., dips 75° SE., and cuts across the schistosity of the country rock at a small angle. The greatest thickness shown was about 5 inches, and the greatest length was about 3 feet. A quartz stringer about an inch thick, which consists of a weathered sugary form of quartz, occurs with the stibnite and lies at some places in the footwall and at others in the hanging wall. Some of the ore at the shaft, which lies several hundred feet west of the crosscuts, appeared to come from a body of ore that is larger than those exposed in the crosscuts. The lenses consisted almost entirely of stibnite of both coarsely granular and finely granular character. The stibnite that has been exposed for a long time to the weather is coated with light-yellow earthy decomposition products (stibiconite?).

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[1] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, p. 9, 1916.

DEPOSITS IN NEIGHBORING DISTRICTS.

A few facts which might be of assistance to the prospector in the Nenana region about lode occurrences in adjacent regions geologically similar are here summarized from Survey reports.[1]

FAIRBANKS DISTRICT.

The rocks in the Fairbanks district are cut by many igneous intrusives. Quartz veins which range from less than an inch to 12 or 15 feet in width are common. These veins have a strike parallel generally to the strike of the country rock, and their dip is in most places steep. A little orthoclase may be associated with the quartz. The quartz of the productive veins is commonly milky white.

The metallic minerals that occur in these quartz veins are pyrite, stibnite, arsenopyrite, galena, sphalerite, bismuth, and gold. Pyrite is the most abundant and under the action of the weather alters to the familiar rusty-brown limonite. Stibnite is found with gold in some of the richest quartz veins. Arsenopyrite is rather abundant and occurs in some places with gold and stibnite. Bismuth intergrown with gold has been picked up in placers, and is reported[2] with bismuthinite (bismuth sulphide) "in a very rich gold-bearing vein quartz." Galena (lead sulphide) that carries silver and sphalerite (zinc sulphide) occur in the Fairbanks district. Cassiterite (tin oxide) and wolframite (tungsten ore) are found in placer concentrates.

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[1] Prindle, L. M., Auriferous quartz veins of the Fairbanks district: U. S. Geol. Survey Bull. 442, pp. 210–229, 1910.

Brooks, A. H., Geological features of Alaskan metalliferous lodes: U. S. Geol. Survey Bull. 480, pp. 43–94, 1911.

Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, 1912.

Prindle, L. M., Katz, F. J., and Smith, P. S., The Fairbanks quadrangle: U S. Geol. Survey Bull. 525, 1913.

Chapin, Theodore, Lode mining near Fairbanks: U. S. Geol. Survey Bull. 592, pp. 321–356, 1914.

[2] Chapin, Theodore, op. cit., p. 325

BONNIFIELD DISTRICT.

Some lode mining has been done on Wood River, the first large river east of the Nenana. This district was visited by a Survey party in 1910. The country rock is quartz-feldspar schist that is cut by intrusive granitic rocks, and the mineralization seems to be related genetically to these intrusives. The deposits appear to be of two kinds—mineralized bodies of schist, or igneous rock, and quartz veins. The gold is associated with pyrite. At one locality a zone of rhyolite porphyry and at another a body of black quartzitic schist, both heavily mineralized with pyrite, are reported to carry gold. On another of the creeks a large quartz vein that consists of massive milky quartz and in places is stained with limonite carries gold, but the assay values were too low to admit of mining under conditions existing at that time.

GOLD PLACERS NEAR THE NENANA COAL FIELD.

By A. G. Maddren.

INTRODUCTION.

The Nenana district lies in the northern foothill belt of the Alaska Range, along the southern border of the Tanana Valley, between 147° 40′ and 149° 20′ west longitude and 63° 50′ and 64° 15′ north latitude. This area has been described under the name "Bonnifield region" by Prindle[1] and Capps.[2] Prindle included all areas of placer mining between Wood River and Nenana River in the "Bonnifield placer region," which is equivalent to the area here called Nenana district. Capps applied the name "Bonnifield region" more broadly to include a large area of the foothill province east of Wood River, in addition to that between Wood and Nenana rivers. The considerable areas of lignite deposits that occupy portions of the Bonnifield placer region, as defined by Prindle, constitute what is now commonly called the Nenana coal field, and as the placer gold deposits discussed in this report are distributed throughout the general area occupied by the lignite-bearing sediments and in some localities are closely associated with them, a common geographic designation for both seems desirable.

The field observations upon which this report is based were made incidentally to detailed stratigraphic work on the lignite deposits of the Nenana coal field during the summer of 1916, under the direction of G. C. Martin. As field work on the lignite deposits was restricted to the western half of the district the observations of the writer on the placers cover only that part of the area. The notes here presented on the placers of the eastern half of the district are based on information gathered from miners and prospectors. The information given in this paper is more or less supplemental to that obtained by Prindle in 1906 and by Capps in 1910, although some of the workings they noted are now abandoned and several others have been developed since their visits. Their reports have been freely drawn upon.

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[1] Prindle, L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, pp. 207–213, 1907.

[2] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, 1912.

GEOGRAPHY.

The part of the northern foothill province of the Alaska Range included in the Nenana district is well marked off on the west by Nenana River and on the east by Wood River. These rivers rise in the main range, to the south, and flow northward, by direct courses in deep valleys, across the moderately mountainous foothill belt. On the south the foothill belt is limited by the higher mountains of the northern front of the Alaska Range, whose rugged ridges attain altitudes of 5,000 to 6,500 feet. On the north the foothill belt terminates with a somewhat abrupt east-west front that stands from 2,000 to 3,000 feet above the Tanana Valley lowlands. These lowlands or broadly terraced plains slope gently northward and extend along the base of the foothills for about 25 miles, to Tanana River. As thus bounded by high mountains on the south, valley lowlands on the north, and large river valleys on the east and west, the Nenana district comprises a rectilinear block of the foothill province, about 50 miles from east to west and 25 miles from north to south, covering thus an area of about 1,250 square miles.

Although considerable areas in the eastern and western parts of the district are drained by tributaries to Wood and Nenana rivers, respectively, its greater part is drained by Totatlanika and Tatlanika creeks, large streams that rise wholly within the central foothill area of the district. These streams, like Nenana and Wood rivers, flow northward across the dominant easterly trend of the foothill ridges. All four of these trunk streams continue northward from the foothills across the Tanana Valley lowlands and discharge into Tanana River. (See Pl. XVII.)

The Nenana district, especially in its western half, exhibits three chief forms of topography. These are, in order of prominence, a series of nearly parallel east-west ridges whose general altitude ranges from 3,000 to 4,000 feet; a series of depressions between the foothill ridges, from 1,000 to 2,000 feet below the crests; and a number of narrow canyons eroded to depths of 500 to 1,500 feet across the mountain ridges from south to north by the trunk streams of the district. Thus the foothill belt as a whole is one of marked diversity, but nevertheless its chief features have a rather regular arrangement, those due primarily to structure trending generally east and those due primarily to drainage development transecting the structural trend south to north.

GOLD PLACERS.

GENERAL CONDITIONS.

The first discoveries of placer gold in the Nenana district were made in 1903 and 1904 by prospectors who came chiefly from Fairbanks, the supply center of the region, on Tanana River about 60 miles to the north. Additional discoveries have been made from year to year on creeks that were not closely examined during the initial period of prospecting, and it is probable that still other localities of gold-bearing gravels may be found here in the future. It is estimated that from 50 to 100 men were engaged in prospecting and mining in the district during the earlier years of development, but during the last 10 years the number has ranged from 30 to 50.

The localities where placer gold is known to occur are distributed throughout the district, in the drainage areas of all the trunk streams. In the Nenana Valley gold is found in the basins of three eastern tributaries to the main river—Moose, Hoseanna, and Healy creeks. In the Totatlanika basin gold occurs on California Creek and its tributaries, Rex and Eva creeks, at a number of points along the main course of the Totatlanika above the mouth of California Creek, and in Daniel, July, and Homestake creeks and McCuen Gulch, tributaries to its upper course. In the Tatlanika basin productive mining has been done on Grubstake and Roosevelt creeks, and gold is reported to be present in Hearst Creek and along the bed of the main stream for several miles. Mining has been done at several localities along Gold King Creek.

In general placer-mining claims have been staked and restaked from year to year on practically every stream of any size in the district, and prospecting has been done at hundreds of points along these streams by digging open cuts and shallow holes.

NENANA VALLEY.

Moose, Hoseanna, and Healy creeks are the three largest tributaries to Nenana River from the east in the foothill belt. They drain considerable areas in the western and southwestern parts of the district.

MOOSE CREEK.

GENERAL FEATURES.

Moose Creek empties into Nenana River about 45 miles above its mouth by the course of the river, or 38 miles by the line of the Government railroad that is now being constructed along the east side of the Nenana to a point about 4 miles above the mouth of Moose Creek, where it is to cross the river and continue southward along its west bank. Moose Creek is about 10 miles south of the northern border of the foothill belt. Its basin comprises about 20 square miles on the eastern slopes of the Nenana Valley. It is formed by two headwater streams, Big Moose and Little Moose creeks, which join about 6 miles from the Nenana. Little Moose Creek flows northwestward, and the main creek continues in the same direction. Big Moose

Creek enters from the northeast, and about 2 miles below its mouth another tributary, Cody Creek, enters from the east. Two miles farther downstream Chicken Creek, the largest tributary to Moose Creek, flows into it from the northeast.

GEOLOGY.

The basin of Moose Creek is eroded in schist that is overlain by a thick mantle of gravels. The schist is best exposed along the deeper parts of the main drainage courses, where the gravels have been eroded away by the streams. The schists are also denuded of the overlying gravels on the divides between the sources of Cody Creek and Rex Creek and between Cody and Chicken creeks. Near the junction of Chicken Creek with Moose Creek the bedrock slopes of the Nenana Valley disappear beneath terraces of gravel several miles wide that extend along Nenana River throughout the foothill belt.

The thick deposits of high gravels that overlie the schists within the Moose Creek basin occur chiefly on the ridges and spurs between Cody, Big Moose, and Little Moose creeks and along the divide at the heads of these streams. On these ridges the gravels range in thickness from 300 to 500 feet, but apparently they are erosional remnants of a considerably greater thickness of gravels which formerly covered the whole Moose Creek basin. These gravels appear to be much thicker north and south of Moose Creek along the eastern slopes of the Nenana Valley and in other parts of the district.

DRAINAGE.

The drainage system of the Moose Creek basin is clearly due to rapid downward erosion by the present streams through the thick gravels and into the underlying schist bedrock. The amount of vertical down-cutting into the schist ranges from 200 to 500 feet along the stream courses.

Nenana River, the controlling factor in the development of this drainage system, has recently intrenched its course to a depth of several hundred feet below an older valley floor several miles wide. The surface of this older valley floor now has the form of broad gravel terraces that extend along the river throughout its foothill section. These broad terraces, together with many narrow ones high on the valley slopes, indicate successively lowered flood plains in the course of the valley's erosion to its present form.

Moose Creek has adjusted itself to the recent abrupt down-cutting of the Nenana by intrenching the lower 2 miles of its course across the broad gravel terraces of the main valley. The down-cutting has been continued up the creek and its larger tributaries nearly to their sources, and in some parts of the basin small gorges have been cut into the schist bedrock. Thus narrow rock benches that represent remnants of an older valley floor have been formed here and there. These rock benches within the Moose Creek basin appear to be directly related to one or more of the broad gravel terraces of the Nenana Valley. Together these features indicate that the more or less rapid down-cutting of Nenana River and its tributaries has been arrested at intervals for periods long enough to enable the streams to work laterally and widen their flood plains. That these periods of arrested down-cutting were not long, however, appears to be shown by the fact that no very wide or continuous benches have been formed within the bedrock portion of the Moose Creek basin.

PLACERS.

The principal placer claims in the Moose Creek basin are on Big Moose and Little Moose creeks and along the main stream for about a mile below their junction. Big Moose and Little Moose creeks are each about 2½ miles in length, but most of the mining on them has been done along the lower mile of their courses. They rise on a gravel ridge, 3,000 feet in altitude, that divides them from Eva and Wilson creeks, which flow eastward into California Creek. The junction of Big Moose and Little Moose creeks has an altitude of about 1,900 feet. Big Moose Creek falls about 300 feet in the lower mile of its course. Little Moose Creek falls about 250 feet in the same distance, and this grade continues down Moose Creek for a mile below the junction.

The first gold production of consequence in the Moose Creek basin is reported to have been made in the later part of the summer of 1909, when about 100 ounces was mined from a gravel-covered bench with schist bedrock near the mouth of Big Moose Creek. Seven men are reported to have mined in this part of the basin in 1910, and since then about the same number of men have been mining each summer. In 1916 eight men were mining on four claims in this basin. Three men were working on a claim on the main creek just below the junction of Big Moose and Little Moose creeks, two men were mining a claim on Big Moose Creek about a mile above its mouth, and two claims were being mined by three men on Little Moose Creek about half a mile above its mouth. Mining on another claim on Big Moose Creek just above the one that was worked was discontinued for the season because the open cut was filled with waste gravel by a flood in June. In fact, the unusually high water at that time set back mining on all the claims in some measure, as it washed out some of the automatic dams used in ground sluicing and carried more or less waste gravel into open cuts that had been prepared for shoveling in.

The yield of placer gold from the Moose Creek basin during the period 1909 to 1916 is stated to have averaged the equivalent of good wages, or about $7 a day to the shovel. It is estimated that the value of the total output of gold to date is about $30,000.

The placer gold occurs chiefly along the present stream beds, associated with gravels from 2 to 4 feet thick. Some gold also occurs with older stream gravels on rock benches that now stand about 15 feet above the streams. It is reported that prospects of gold may be obtained at some points in the high gravels that rest on the upper slopes of the valley, but no mining of these gravels has been attempted. The gold has not been found in pay streaks, but so far as mining has disclosed appears to be distributed in more or less disconnected patches of gravel or pockets in the bedrock.

Cody Creek is reported to contain prospects of placer gold, but no mining was being done on it in 1916. A lode of stibnite (antimony sulphide) occurs in the basin of this stream and may be associated with gold that is the source of the placer prospects.

Chicken Creek is about 5 miles long and has its source against that of Rex Creek to the east. No placer gold is known to have been mined from this stream, although evidences were observed of claims having been staked along its course. Lignite-bearing sediments occur in a small area along the north bank of Chicken Creek, about half a mile above its junction with Moose Creek, and small quantities of this lignite have been utilized as forge fuel by the miners for sharpening picks, but it is stated to be of inferior quality.

MINERALIZATION AND SOURCE OF THE GOLD.

Antimony sulphide occurs in the valley of Cody Creek. Another locality of sulphide mineralization was discovered in 1916 on Little Moose Creek near its source, in a saddle that divides it from Eva Creek. The chief metalliferous mineral at this prospect is gold-bearing arsenopyrite, one assay of which shows a value of $24 to the ton.

This mineralization is believed to be directly connected in origin with dikes and stocks of igneous rock intruded into the schists of the Moose Creek basin at several localities and with other intrusives that are probably present but not now known.

From the evidence at hand the writer is strongly inclined to credit the chief source of the placer gold of Moose Creek basin to mineralized zones in the schist bedrock and to consider that the gold, at least in greater part, has been derived directly from the schists by the erosion of the present streams since the schists were denuded of the thick overlying gravels. In other words, the overlying gravels are not considered to have contributed very much gold to the present placers of Moose Creek.

HOSEANNA CREEK.

GENERAL FEATURES.

Hoseanna Creek, sometimes called Lignite Creek, is a large stream about 15 miles in length that discharges into Nenana River from the east about 12 miles south of Moose Creek. The valley of this stream is 3 or 4 miles wide from north to south and as a whole forms a marked depression in the east-west foothill belt. This depression is almost entirely occupied by a thick formation of lignite-bearing sediments, of early Tertiary (Eocene) age, that are but slightly consolidated. Because of the relative softness of the lignite-bearing formation, Hoseanna Creek and its tributaries have been able to erode the valley deeply, bringing the drainage into adjustment with the most recent down-cutting of Nenana River. As a result of this rapid intrenchment practically all the streams of the Hoseanna Valley flow in gorges bounded by bluff slopes from 100 to 300 feet high, and the flood plains of the streams are narrow. Even the valley floor of the main stream is in few places more than a quarter of a mile in width.

The Hoseanna Valley is bounded on the south by a ridge of schists that forms the divide between it and the valley of Healy Creek. On the north it is separated from the drainage basin of California Creek and the headwaters of the Totatlanika by broad ridges that are composed chiefly of the lignite-bearing formation of the district, overlain by high gravels such as occur about the sources of Moose Creek. In fact, these high gravels extend continuously along the eastern slopes of the Nenana Valley from the head of Moose Creek to the lower part of the Hoseanna Valley.

Prospects of placer gold are reported to occur in the bed of Hoseanna Creek about 3 miles above its mouth and on Popovich and Sanderson creeks, two of its tributaries.

POPOVICH CREEK.

Popovich Creek empties into the Hoseanna from the north about 6 miles above its mouth. It is about 4 miles long and drains a deep gulch like most of the other tributaries to the main stream, especially on the north. The lower 1¼ miles of Popovich Creek is deeply intrenched across the lignite-bearing formation of the valley, whose beds here trend east and dip north. The upper course of the stream and its several headwater branches are deeply eroded into the high gravels that overlie the lignite formation. These gravels are very thick on this part of the northern divide of the Hoseanna Valley and in their basal portions, along the stream cuts, show stratification with structural dips of 10°–15° N. that are similar to those of the lignite-bearing sediments beneath them. This indicates that at least a part of the gravels have been deformed to about the same degree and in the same manner as the lignite-bearing sediments. Higher on the slopes, however, structural deformation of the gravels is not so evident and much of the material seems to be reworked gravel that lies horizontally upon the beveled strata of the older gravels.

Stream gravels resting on a lignite-bearing bedrock along the lower course of Popovich Creek are reported to contain some placer gold. A small amount of prospecting of these gravels was done during 1916 by one man. As these present stream gravels are without doubt derived chiefly from the tilted gravels that structurally overlie the lignite formation in the upper part of the valley it seems most reasonable to assume that the source of any placer gold in this valley must be in the old tilted gravels. These gravels, however, have not been prospected thoroughly enough to justify definite conclusions regarding the placer gold they may contain. The conditions, both stratigraphic and erosional, presented on Popovich Creek appear to be the same as those in the lower part of the Healy Creek valley, a few miles to the south, where the lignite formation is overlain by a great thickness of tilted gravels that seem definitely to contain placer gold. (See p. 372.)

SANDERSON CREEK.

Sanderson Creek is a large headwater branch of Hoseanna Creek about 5 miles long that discharges into the main stream about 10 miles above its mouth. The lower mile of this creek is intrenched in the lignite formation; its middle course lies along the contact between the lignite formation and the underlying schists; and the upper half of its valley is entirely in the schists. These schists form the mountainous ridge that divides the Hoseanna Valley on the north from the Healy Valley on the south. The upper part of Sanderson Creek has eroded its valley into these schists to a depth of 1,000 feet or more.

A number of placer claims have been located and relocated along Sanderson Creek during the last 10 years, but no mining of consequence appears to have been done on any of the claims. At several points along the middle course of the creek there are abandoned sluice boxes which apparently have not been used recently. Several men are reported to have worked on this creek in 1906, and many of the claims have been relocated since that time.

Prospecting on this creek seems to have been confined to its middle course, where the stream flows along the contact between schists on the south and the lignite formation on the north. To judge from the general geologic conditions of the valley this part of Sanderson Creek does not appear to be as favorable for placer gold as its upper part, where the headwater branches are eroded entirely in highly metamorphosed schists exhibiting evidences of strongly sheared zones with quartz vein mineralization.

HEALY CREEK.

GENERAL FEATURES.

Healy Creek is the largest tributary to Nenana River from the east in the foothill belt. It is 25 miles long and discharges into the Nenana about 5 miles south of Hoseanna Creek, or 54 miles above the mouth of Nenana River by the line of the Government railroad now being built up this valley. The valley of Healy Creek trends almost directly west and is comparatively broad but deep, its slopes rising 1,500 to 3,000 feet, from an old valley floor about a mile wide, to divides that stand 5 or 6 miles apart. The older floor of the valley is now represented by benches from 100 to 300 feet above the present flood plain, which is relatively narrow. These benches have been produced by the recent intrenchment of Healy Creek and its tributaries. The tributaries have not only cut sharp, narrow gorges across the benches but have eroded deep gulches up the valley slopes well toward their heads. The valley previous to its recent intrenchment appears to have had a U-shaped cross section, with rather smooth slopes and a broad, flat floor that strongly suggests former occupation and molding by a glacier. The intrenchment of this valley, like that of Moose and Hoseanna valleys, has been controlled by and is in adjustment with the recent downward erosion of Nenana River across the foothill belt. The mountain summits along the southern divide of the Healy Creek valley have altitudes of 5,000 to 6,000 feet and may be considered to mark the northern front of this portion of the Alaska Range.

GEOLOGY.

The greater part of the Healy Creek valley is eroded in micaceous and quartzitic schists. Practically all the slopes and divides of the valley on both sides are composed of schistose rocks except along the western 6 miles on the north, where there is a thick series of semiconsolidated gravels underlain by lignite-bearing sediments.

Although the schistose bedrock of the valley might appear favorable for gold mineralization from which placers might be concentrated, no placer gold deposits whose origin is directly related to the present erosion in the schists have been found within the valley.

The only valuable deposit of placer gold known in the Healy Creek valley is closely associated with the thick gravels that overlie the lignite formation in the lower part of the valley on its north side. As this occurrence seems to afford evidence of the presence of placer gold in some parts of the old gravels of the region the essential geologic relations of these gravels to the older rocks in this locality are here considered in some detail in order that comparisons may be made with other localities.

The geologic section of the lower 10 miles of the Healy Creek valley comprises schists, lignite-bearing sediments, and a great thickness of gravels. The schists form the south slopes of the valley and may be dismissed from further consideration with the statement that the lignite-bearing formation rests upon them unconformably.

The lignite-bearing formation extends along the bottom of the valley throughout its lower 10 miles as a belt about 1 mile wide, whose general structural trend is west, corresponding with the direction of the valley. Nearly all the western half of this belt lies on the north side of Healy Creek, and the greater part of its eastern half lies on the south side—that is, Healy Creek cuts the belt transversely about the middle of its length.

The lignite beds in this belt strike S. 65°–80° W. and dip 25°–35° N. The stratigraphic thickness of the formation is fully 1,500 feet and possibly 2,000 feet, to judge from measurements made by Prindle[1] about 2 miles above the mouth of Healy Creek and by Capps[2] about 6½ miles above the mouth.

In the downstream half of the belt, where the top of the lignite-bearing beds extends along the benches and lower north slopes of the valley, the strictly lignite-bearing sediments are overlain, with what may or may not be depositional conformity, by about 500 feet of soft sandy shales that appear to be practically barren of lignite beds, although they contain some thin disconnected layers of lignitized vegetable remains. The relation of these sandy shales to the lignite-bearing beds beneath them appears to be close; but their somewhat different lithologic character and the apparent absence of well-developed beds of lignite in them seem to point to the conclusion that they are not of the same age as the typical lignite-bearing sediments of the region. In this connection it is suggestive that in another part of the district, on Roosevelt Creek near its mouth, plant-bearing beds possibly younger than the typical lignite formation of the region are indicated by fossil leaves that occur in a considerable thickness of fine sediments beneath thick gravels. (See p. 399.) On Roosevelt Creek, as on lower Healy Creek, placer gold in the present stream gravels appears to be derived from older placers in the thick deposits of gravels that seem to overlie a considerable thickness of fine sediments which are younger than the typical lignite-bearing formation of the region. Brooks[1] has discussed the stratigraphic features here mentioned, but at the time of his writing there were no data available about the occurrence of placer gold in the old gravels of the Healy Creek valley.

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[1] Prindle, L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, p. 223, 1907.

[2] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 57, 58, 1912.

The sandy shales just considered are overlain by about 200 feet of strongly cross-bedded sands containing lenticular beds of gravel and a number of pieces of lignitized wood that have the appearance of having been deposited with the sands and gravels as stream-washed driftwood. The upper part of this 200 feet of cross-bedded sands and gravels grades upward into coarse heavy-bedded gravels whose stratigraphic thickness is at least 2,000 feet. This thick deposit of gravels has been named the Nenana gravel by Capps.[2]

The strong cross-bedding of the sands immediately beneath the typical Nenana gravel in the Healy Creek section and the heavy bedding of the gravels themselves furnish ample evidence that these sediments have been laid down by streams that were much more vigorous than those of the drainage system which existed during the deposition of the lignite formation and the overlying 500 feet of sandy shales in the Healy Creek valley. Observations made by the writer 4 to 6 miles above the mouth of Healy Creek seem to indicate that the cross-bedded sands immediately beneath the heavy-bedded gravels are a basal phase of the Nenana gravel composed chiefly of reworked sediments derived from the older lignite-bearing sediments and associated sandy shales, these older sediments apparently having been locally subjected to strong stream erosion and redeposition during the initial stage of drainage development that produced and built up the thick Nenana gravel.

The character of the Nenana gravel in the Healy Creek valley may be observed to advantage along the courses of several small tributaries that have eroded deep gulches across the stratification of the gravel from north to south. To judge from the cleanest exposures along these gulches, the gravels are moderately coarse throughout their thickness of 2,000 feet or more. They contain a considerable proportion of cobbles as much as 6 inches in diameter. Most of the pebbles are between 1 and 2 inches in diameter, and the percentage of pebbles less than 1 inch in diameter is relatively small. However, there is enough sand and grit mixed with the pebbles to compact them firmly as a whole, and at some horizons these finer sediments form beds several feet in thickness that are continuous as distinctive strata for considerable distances.

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[1] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 102, 103, 1911.

[2] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 30–34, 1912.

The Nenana gravel comprises pebbles of schist, quartzite, slate, black, green, and red chert, white vein quartz, granite, and a variety of other igneous rocks. All these rocks are known to occur in the Alaska Range, from which the chief part of the gravel is believed to have been derived. The most abundant pebbles appear to be those of vein quartz and quartzite. Some of the schist fragments at or near the base of the deposits in some localities are flat, slabby, and angular and do not seem to have been transported far from their bedrock source, but the thoroughly rounded and polished condition of most of the pebbles and cobbles indicates they have been subjected to considerable wear by running water and that probably they have been transported some distance.

Although there are a number of large boulders, some of which are 10 to 15 feet in greatest dimensions, in the beds of the gulches that dissect the Nenana gravel in the Healy Creek valley, it is not clear that these are derived from the older gravels, for few of the boulders observed actually embedded in the stratified gravels where they are freshly exposed along the gulches are more than 1 foot in diameter. The writer is inclined to consider that practically all the very large boulders that occur in the present stream beds or upon the slopes and benches of their valleys have been derived from glacial deposits that were laid down on an older surface of the gravels before they were eroded to their present form.

The prevailing color of the gravels is rusty brown, owing to the deep and general oxidation they have undergone. The fine sediments that occupy the spaces between the pebbles are in places slightly cemented by iron oxide, and some strata of considerable thickness are consolidated to conglomerate. This cementation, however, is rarely firm enough to resist atmospheric disintegration and as a result the gravels yield rapidly to erosion. Even comparatively small streams cut deep gulches into the gravels, as may be observed in the Healy Creek valley, and larger streams erode valleys of considerable width. The ready erosion of these gravels is probably due largely to the fact that well-rounded pebbles are easily moved by comparatively small volumes of running water.

The Nenana gravel is well developed along the upper north slopes and divide of the Healy Creek valley for a distance of about 4 miles, from 2 to 6 miles above the mouth of the main stream. The tilted gravels that now occupy this area are apparently only a remnant of a belt that formerly extended considerable distances to the east and to the west. The eastern portion appears to have been removed through erosion by Healy Creek and the western portion through erosion by Nenana River.

In the section on Healy Creek the gravels present a measurable stratigraphic thickness of at least 2,000 feet, and it is probable that they may have a maximum thickness of 3,000 feet in this locality.

The dominant bedding planes of the thick Nenana gravel and of the immediately underlying cross-bedded sands that are considered to be a local basal phase of the gravel on Healy Creek appear to have practically the same trend. The strikes are from west to N. 85° W.; the dips are rather uniformly 19° N. throughout the lower 1,000 feet of the gravel and 15°–35° N. in the upper 1,000 feet.

The northward dip of these sediments appears to be primarily due to a fault movement that has tilted not only the gravels but likewise the lignite formation beneath them, the two having been brought to their present attitude as a structural unit or block. The trend of this fault is east (in general parallelism with the strike of the gravels, and the movement along it has resulted in the downthrow of the Nenana gravel to the south so that it now abuts abruptly against schists that mark the north (upthrown) side of the fault. These schistose rocks form the divide between Healy and Hoseanna valleys.

The section of the Healy Creek valley thus shows a thickness of at least 4,000 feet of stream-laid sediments, the lower and upper halves of which differ in general lithologic character and appear to have a distinguishable discordance in strike, although the differences in dip are not so pronounced. The average difference of strike between the lignite formation and the Nenana gravel appears to be about 20°; and the average dip of the gravel, at least in its basal members, appears to be somewhat less than that of the lignite formation.

This apparent discordance in structure appears to indicate a depositional unconformity between the lower and upper halves of the section that is also marked by the differences in character of the sediments. These differences, however, are not equally evident in all exposures and may be practically unrecognizable at some points. Nevertheless there seems to be little question that there is in this locality an unconformity due to a change in the drainage conditions between the period during which the lignite-bearing sediments were deposited and the period during which the thick gravels were accumulating. The drainage conditions of the earlier period appear to have been those of comparatively moderate stream erosion with deposition, favorable for the formation of lignite beds; and the drainage conditions of the later period were evidently those of very vigorous stream erosion which in the beginning was strongly degrading and favorable for the production and transportation of great quantities of well-rounded gravels. This later period of vigorous erosion was also favorable for the production of placer gold in areas where the country rocks contained lode gold.

PLACER GOLD.

Placer gold occurs in the present stream gravels of three tributaries to lower Healy Creek—Alaska, French, and Home creeks, named in upstream order. These streams are from 2 to 3 miles in length and discharge into Healy Creek from the north about 3, 4, and 5 miles, respectively, above its mouth. Although the volume of these streams is comparatively small they have eroded gulch valleys to depths of 300 to 600 feet across the Nenana gravel, which forms the upper north slopes of this part of the valley. This deep erosion by streams so small is accounted for partly by the stream grade, which is between 250 and 300 feet to the mile, and partly by the fact that the gravels are only slightly cemented and are well rounded.

These gulch valleys are eroded in practically no other deposits than the Nenana gravel, except that glacial deposits may have formerly overlain the gravels and have since been removed from the areas now drained by the streams. The only evidence of the former presence of glacial deposits found in these drainage areas consists in large boulders that occur with the recently washed stream gravels, chiefly along the beds of the gulches. These boulders do not appear to be derived from the tilted gravels, and their large size and variety of composition suggest that glaciers were the only agency competent to transport them to their present positions.

It seems probable that any placer gold in the present stream gravels of French and Alaska gulches is derived from the Nenana gravel, and this conclusion is also supported by the evidence as to the derivation of the placer gold in the present stream gravels of Home Creek, for the schists on the upper course of this stream do not appear to have produced placer gold during the erosion of the gulch.

There are no definite data at hand as to whether the placer gold in the Nenana gravel is confined to a few particular stratigraphic horizons in these gravels or is somewhat widely scattered throughout their thickness. So far as known no attempt has been made, even of a superficial character, to prospect for gold in the Nenana gravel itself. It is significant, however, that placer gold is known to occur at about the same horizon in each of the three large gulches that transect the Nenana gravel in Healy Creek valley. From the evidence furnished by the distribution of the reconcentrated placer gold in these gulches it seems likely that this gold has its chief source in the lower 500 feet of the Nenana gravel.

It is not known when placer gold was discovered in these gulches, but the first mining seems to have been done in 1913 on Home Creek, which is the largest of the three.

HOME CREEK.

Home Creek is about 3 miles long. Its lower half flows in a direct course somewhat east of south across the belt of Nenana gravel, and its upper half flows east along or near the fault line that marks the northward limit of these tilted gravels in this valley. The upper section of Home Creek thus seems to have had its position and direction determined by the fault. The upper section of this valley has been eroded almost entirely in the gravels, for the schists that form the north slopes of the valley appear to have been little more than cleared of the gravels that formerly abutted against them, and only a few steep gulches have been cut into the schistose rocks by short tributaries.

It is reported that no placer gold has been found in the material eroded from these gulches in the schists and practically none in the stream gravels along the upper half of Home Creek, although it is evident that a great quantity of the Nenana gravel has been removed from this part of the valley. This apparently indicates that the schists of the north slopes of the upper valley have not been eroded sufficiently to produce placers, even if they contain gold, and that the part of the Nenana gravel that has been removed by erosion along the fault line does not contain sufficient placer gold to form valuable deposits even after the concentration of a large quantity of gravel. The structural attitude of the Nenana gravel in the Healy Creek valley indicates that the part of it that has been eroded away along the upper valley of Home Creek is from 1,000 to 2,000 feet above the base of the section.

The lower 1½ miles of Home Creek has eroded a gulch across the Nenana gravel belt of the Healy Creek valley to a depth of about 500 feet. The present flood plain of the stream occupies practically the whole width of the bottom of this gulch, which is narrow throughout its length, being in few places more than 150 feet wide. The grade of the bed of Home Creek is between 5 and 6 per cent, consequently the transportation of the well-rounded gravels along it is very active, especially during times of flood, when the volume of water is probably sufficient to occupy the whole bed of the gulch. All the gravels along the bed of the gulch are cleanly washed, very little fine sediment being deposited with them. The flood plain gravels rarely accumulate to a greater thickness than 4 or 5 feet, and their average thickness is about 2 feet. However, the stream is often temporarily clogged and diverted from one side of its flood plain to the other by large slides of gravel from the steep gulch slopes.

The cross-bedded sands and gravels that are considered to form the basal part of the Nenana gravel in the Healy Creek valley are exposed in low bluffs at the mouth of Home Creek, where that stream enters the flood plain of Healy Creek. Thus the lower 1½ miles of Home Creek is eroded across the whole stratigraphic thickness of the Nenana gravel as developed in this locality, and the bedrock upon which the recent gold-bearing stream gravels of Home Creek rest is composed entirely of the tilted Nenana gravel. This gravel is semiconsolidated along Home Creek gulch, but in general its cementation is so slight that it will barely stand upon exposure to ordinary disintegration, although a few members have more resistance than others and present more or less distinct outcrops along the valley slopes, chiefly in fresh exposures caused by slides. The gravel bedrock along the immediate course of Home Creek, however, appears to be quite uniformly compact and must be loosened with picks in mining.

Most of the mining on Home Creek has been done in the bed of the stream from one-fourth to three-fourths of a mile above its mouth. In 1913 four men brought two boatloads of supplies to the mouth of Home Creek from the Tanana by way of Nenana River and Healy Creek and began operations, which have been conducted along this section of the creek each summer since by two or three men. The method consists of groundsluicing the present stream gravels down to the bedrock of semiconsolidated gravel and shoveling the material thus concentrated into sluice boxes together with a few inches of the bedrock after it has been loosened with picks.

The gold recovered is fairly coarse and worn. It consists of about equal proportions of shotlike nuggets, whose value varies from 25 cents to $1, and of heavy flakes, from one-eighth to one-half of an inch in dimensions, that have been flattened or bent as if hammered and rolled by moving pebbles.

Owing to the rough and uneven character of the coarse semiconglomeratic bedrock, care has to be exercised in cleaning the surfaces of cuts after the stream gravels have been concentrated down to them. All seepage water must be excluded to prevent the loss of gold from the shovels, and it is probable that a certain amount of fine gold is lost in spite of careful shoveling.

The value of the gold produced on Home Creek for the four years of mining that has been done probably does not exceed $4,000.

FRENCH AND ALASKA GULCHES.

French and Alaska gulches are eroded in the Nenana gravel belt from north to south, in the same manner as the lower half of Home Creek, with the difference that their streams have not worked headward across the entire width of gravels to the schists on the north. The volume of these streams is considerably less than that of Home Creek; but nevertheless the gulches are eroded into the gravel to depths of 300 to 500 feet, and thus expose a considerable stratigraphic thickness of the gravel from the base upward.

Prospecting on both these gulches has demonstrated that their present stream gravels contain placer gold, but mining has not been undertaken because of insufficient water supply. In Alaska Gulch nuggets whose value is from $2 to $3 have been found.

TOTATLANIKA BASIN.

PRINCIPAL FEATURES.

Totatlanika Creek is a large stream, about 60 miles long, the upper half of which lies wholly within the foothill belt and the lower half within the Tanana Valley lowlands. The lowland section flows northward from the foothills by a direct course that is parallel with the corresponding section of Nenana River, about 15 miles to the west.

The basin of the upper half of the Totatlanika covers an area of about 275 square miles. The eastern part of this basin is drained by the upper section of the main stream and its western part by a large branch named California Creek. California Creek and the upper Totatlanika lie 5 to 7 miles apart and flow northward roughly parallel to one another across the greater part of the foothill belt to the southern flanks of the northernmost foothill ridge, beyond which they converge and join to form the main Totatlanika. From this junction the main stream flows northward to the Tanana Valley lowlands through a narrow, recently eroded valley 1,000 to 1,500 feet deep and 5 miles long.

Broadly considered the foothill part of the Totatlanika basin is characterized by a succession of three highland and three lowland belts that alternate with one another and trend east in general parallel arrangement. Each of these contrasting belts presents more or less continuity of form within itself, although they vary somewhat in this regard and also in width, which is in general from 3 to 5 miles. The mountain summits along the high belts have altitudes of 3,000 to 4,000 feet, and the bottoms of the valleys in the low belts stand from 1,000 to 2,000 feet lower.

The lowland belts are occupied chiefly, especially along their bottoms and lower slopes, by the lignite-bearing sediments of the region, which rest upon schists and are overlain in some places by thick gravel deposits. The semiconsolidated state of these sediments accounts for the deeply eroded forms they now present. The highland belts are composed almost entirely of hard schistose rocks, although in some areas the lignite formation and high gravels extend up on the higher slopes to considerable elevations above the valley bottoms, and a few isolated patches of these sediments lie near and even upon the crests of the schist ridges.

It seems clear from the distribution and attitude of the schists and overlying lignite sediments that the primary factors in the development of the highland and lowland belts are the regional folding and faulting that deformed the foothill region after the lignite deposits and at least some of the overlying gravels were laid down and before the present drainage system had dissected the region so deeply. Nevertheless it is evident that the removal of large quantities of material by differential erosion in the alternating belts of hard and soft rocks after they were deformed has been the most important factor in forming the lowland belts and accentuating the intervening highland belts.

California Creek and the upper Totatlanika flow northward across the eastward-trending highland and lowland belts through a corresponding succession of narrow canyons and wide basins, and in consequence their valleys present considerable diversity in topographic development and a variety of conditions that control the distribution of stream gravels.

It is probable that the present drainage system originated on an approximately even land surface that sloped northward from the high flanks of the Alaska Range to the Tanana Valley lowlands, and that its arrangement has not been disturbed to any extent since its establishment. Apparently few prominences of the hard schistose rocks that underlie the sedimentary deposits of the region in which the greatest amount of erosion has taken place projected above the sloping surface of the foothill belt when the present drainage system established its direct northward courses, for otherwise the stream courses would probably have assumed a more complicated form than they now exhibit.

CALIFORNIA CREEK VALLEY.

GENERAL FEATURES.

California Creek is about 20 miles long, and its valley comprises two well-developed basin areas, situated along its lower and middle courses, and a less well defined headwater basin that lies along the south flanks of a prominent isolated mountain mass named Jumbo Dome. These three basins are separated by two belts of schist through which California Creek has cut deep canyons. The canyon section between the lower and middle basins is about 3 miles long and 1,000 feet deep, and the one between the middle and headwater basins, around the west flank of Jumbo Dome, is about 1 mile long and several hundred feet deep.

Prospecting for placer gold has been carried on throughout the valley of California Creek. Evidences of this work in the form of holes and open cuts may be observed at a number of points along the main stream and many of its tributaries. Mining operations, however, have been undertaken only at three widely separated localities, two of which have been abandoned for several years. One of these localities is on Rex Creek, a large tributary to the main stream from the west in its lower basin; another is on California Creek where it enters the canyon between the middle and lower basins; and the third is on the upper part of Eva Creek, a tributary from the west that drains the southwestern portion of the middle basin. The last-named locality was the only one in the valley where placer mining was being done in 1916.

REX CREEK.

Rex Creek is about 8 miles long and flows eastward to enter California Creek about 2½ miles above the confluence of that stream with the upper Totatlanika. The headwaters of Cody and Chicken creeks, tributaries of Moose Creek, lie immediately west of the sources of Rex Creek.

The upper 5 miles and the upper slopes of the lower 3 miles of the Rex Creek valley are practically all eroded in schist. The bottom and lower slopes of the lower 3 miles of the valley are occupied by the lignite formation, and a narrow strip of these sediments extends along the north bank of the stream in its middle 2 miles. There is also a small remnant of these sediments in the saddle at the head of the valley between Rex and Chicken creeks. It is probable that the lignite formation formerly extended along the whole length of the valley, at least in its bottom part, before it was eroded to its present depth. Thus the schist along the upper 5 miles of Rex Creek has probably not been denuded of the lignitic sediments for a long period of time and therefore a comparatively small amount of recent stream erosion has taken place in the schist. A measure of this erosion seems to be afforded by narrow gorges in the schist about 50 feet in depth along some sections of the headwaters of the creek and particularly by a number of sharp gulches that have been eroded in the schist along the southern slope of the upper half of the valley.

Placer claims have been located and relocated along Rex Creek throughout its length since 1905, and a considerable amount of prospecting has been done at a number of points in the present stream bed and on benches in areas of schist and of lignitic sediments, but so far the only section of the valley where mining has been undertaken is between 3 and 4 miles above the mouth of the stream, and operations here have been abandoned for several years.

Along the upper half of Rex Creek no profitable placer-gold deposits appear to have been found, or rather it has been stated that the value of the deposits is not sufficient to encourage mining with the amount of water available in this part of the valley.

The middle section of the valley, between 3 and 4 miles above its mouth, where the best prospects of gold appear to occur and where mining has been done at several places, occupies a basin-like expansion above a gorge or wide canyon that is cut by the main creek to a depth of 200 feet across the nose of a spur of schist that projects from the north slope of the valley. This expansion extends southward up the valley of a large tributary that drains the high schist ridge which forms the valley slopes. The headwater branches of this tributary have eroded deep gulches in the schist ridge, and across the upper parts of these gulches the schist is intruded by several dikes. No mineral deposits were observed in the schist in actual connection with these dikes, but quartz veinlets occur here and there throughout the schist. A smaller gulch tributary flows from this schist ridge into Rex Creek about half a mile upstream from the large tributary, and the most extensive placer deposits that have been mined are on a low sloping bench that extends along the south side of Rex Creek between these gulches. The schist of the spur that separates these tributaries extends down into the bottom of the main valley and forms the bedrock upon which the gold-bearing gravels rest.

The sloping bench in which most of the mining has been done is about 500 feet wide, and its upper margin stands about 50 feet above Rex Creek. To judge from the tailing dumps of the old workings practically all the bench gravels consist of the schistose rocks of the valley. These gravels range in thickness from 4 to 8 feet, and the schist bedrock upon which they rest shows considerable decay, as if it had been protected from stream erosion for a long time since the gravels were deposited upon it. The gravels also appear to show the effect of decay since they were laid down. They are fairly coarse but contain no boulders that can not be easily handled.

Capps,[1] who visited this locality in 1910, states that the gold occurs in the basal part of the gravels close to bedrock and that some of it has penetrated into the decayed schist to a depth of about a foot. The gold is stated to be bright and fairly coarse. At the time of Capps's visit three men were engaged in mining this bench ground, but the operations were discontinued in the middle of that summer because the returns were insufficient to make pick and shovel work profitable. Apparently mining has not been resumed at this locality since 1910.

Water for washing the gravels was brought from Rex Creek and the small gulch tributary at the upper end of the bench by a ditch, about half a mile in length, dug along the upper edge of the bench. The workings consist of several open cuts that extend from the ditch across the bench diagonally down the valley, and their area and the quantity of tailings indicate that a considerable yardage of gravels was mined.

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[1] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, p. 47, 1912.

In the bed of Rex Creek just above and below the mouth of the large tributary that enters from the south open cuts have been dug across several of the sharp meanders of the main stream, probably with the combined purpose of testing the recent gravels in these bends and later serving in combination with dams to divert the main creek from its channel in order that its present bed might be prospected. In the gorge by which Rex Creek discharges from the basin-like area along its middle course may be observed the remains of several wing dams that were evidently built for the purpose of diverting the main creek in order that the present stream gravels and schist bedrock might be prospected, but no information is at hand as to the results of this work. However, it has been reported that all of these attempts at mining in the bed of the main creek were handicapped by the difficulty of obtaining adequate drainage for thorough prospecting.

It is reported that the value of the total quantity of gold produced from Rex Creek is about $5,000.

CALIFORNIA CREEK.

The only known attempt to mine the gravels in the main valley of California Creek was made at the head of the canyon that separates the middle from the lower basin of this valley, about 5 miles above the mouth of Rex Creek. Two men worked at this locality during a part of the summer of 1910, digging a bedrock drain along the eastern margin of the present flood plain, where it is bounded by a low gravel bench that represents a previous flood-plain level. It is stated that the stream gravels were found to be about 6 feet deep and to rest on schist bedrock, but that their gold content is not sufficient to warrant pick and shovel mining.

The source of the placer gold that is reported to occur in the present stream gravels at the head of this canyon of California Creek was probably in the schist bedrock, in which the upper end of the canyon is eroded. Quartz veins are numerous in a high detached hill of schist immediately west of the head of the canyon. Some of these veins are 8 to 10 inches thick in their wider parts, and much of the quartz is stained with iron oxides, indicative of metallic mineralization. It is not improbable that some of these veins contain gold, although none was observed, and it appears unnecessary to assume that the placer gold at the head of the canyon was derived from the sediments, or more particularly the high gravels that overlie the lignite formation and that have been removed from the middle basin of California Creek.

EVA CREEK.

Eva Creek, together with a tributary of about equal size named Elsie Creek, drains a large area in the northwestern part of the middle basin of California Creek. It is about 5 miles long and rises on a high gravel-capped ridge opposite Big Moose Creek to the west. The stream flows about due east along the northern border of the middle basin and empties into California Creek about half a mile below the head of the canyon between the middle and lower basins. Eva Creek in eroding its present outlet into the California Creek canyon has cut a subsidiary canyon through schist along the lower half mile of its course and thus has isolated the prominent schist hill that contains quartz veins described in connection with the placer deposits in the upper part of the main canyon. This hill has the appearance of formerly being a part of a spur from the main schist ridge to the north, and it is very probable that the lower course of Eva Creek discharged into California Creek around the south flanks of the hill before the canyon of California Creek was eroded to its present depth; or it may be possible that California Creek discharged at one time through the canyon section of lower Eva Creek.

A large part of the Eva Creek valley is eroded in the high gravel deposits that overlie the lignite-bearing sediments of the middle basin of California Creek, but apparently the lignite formation has not been exposed by the erosion of this stream. These gravels, together with some associated sands and silts, occupy the greater part of the valley, especially in its middle 3 miles, where they cover all of the low divide on the south between Eva and Elsie creeks and extend along the northern slopes of the valley up to their middle heights in the form of benches that rest against the upper slopes of schist.

Along the upper 1½ miles of Eva Creek the bottom of the valley is occupied by a considerable area of schist from which the covering of high gravels has been removed by comparatively recent stream erosion. The high gravels that now surround this schist area and form the upper slopes of the headwater basin have the appearance of being the erosional remnants of a much thicker deposit of gravels which formerly not only occupied the whole headwater basin but extended downstream throughout its length. These gravels are the eastward extension of those that occur on the interstream ridges of the Moose Creek basin and form the divide between Moose and Eva creeks. There is also another considerable area of schist, denuded of the high gravels by recent stream erosion, on the western slopes of the basin of Wilson Creek, a headwater tributary to Eva Creek from the southwest. The present configuration of the Eva Creek valley indicates that at least 300 feet of the high gravel has been eroded from this valley along the course of the present stream below the mouth of Wilson Creek, which joins Eva Creek about 3 miles above its mouth.

The depth of erosion that has occurred in the area of denuded schist in the upper basin of Eva Creek may also be estimated. The upper slopes of this headwater basin are composed chiefly of the high gravels, and to judge from the height of the base of these gravels above the present bed of the stream the schist along the bottom of this basin has been eroded to a depth of about 300 feet since it was denuded of the gravel cover. Thus a considerable amount of schist has been removed from this part of the valley over an area of about half a square mile. This erosion of the schist in the upper basin of Eva Creek and its tributary basin of Wilson Creek is comparable to that which has occurred along the courses of Big Moose and Little Moose creeks, across the divide 1 to 3 miles to the west (described on p. 366), but on Eva Creek the quantity of schist eroded away has been much less.

As on other streams in the district, placer claims have been located along Eva Creek for the last twelve years. The first attempt at mining, however, seems to have been made in 1915, when two men opened a small cut in the stream bed in the schist area of the upper valley. This work demonstrated that there is a small quantity of placer gold in the present stream gravels at this point and also disclosed indications of lode mineralization in the schist bedrock. These indications consist of heavy pieces of schist float that contain arsenopyrite and native bismuth in considerable amount, together with small amounts of other sulphides. Panning tests of this float lode material show that it contains some flour gold in a free state together with a few larger pieces of gold that have sharp angular edges and crystalline faces. Assays of the sulphides show that they are gold bearing, so that a source of gold from which placers might be derived is indicated in the schists of upper Eva Creek. The lode mineralization of Eva Creek and Moose Creek is described elsewhere by R. M. Overbeck. (See pp. 360–361.)

In 1916 a more comprehensive placer-mining operation was undertaken on Eva Creek about a quarter of a mile downstream from the locality where work was done in 1915, at a point about a quarter of a mile above the mouth of Wilson Creek. Here three men built an automatic dam and groundsluiced a cut in stream gravels 3 to 4 feet thick.

The bedrock upon which the stream gravels of this claim rest is composed of the stratified gravels and sands of the basal part of the high gravel deposit that overlies the schist in this valley. These old gravels are here cemented by iron oxide to a somewhat firm conglomerate. As exposed in a bluff on the south side of the creek, opposite the workings, near their contact with the schist, they strike northeast and dip 23° SE. Thus it is evident that the stratified gravels and sands are upturned along the flanks of the schist upon which they rest and that the present stream has beveled them in forming its flood plain. No evidence was observed that the placer gold in the stream gravels of this claim has its source in the bedrock of tilted and cemented gravels, although such a source is possible. On the other hand, it is more probable that the placer gold is derived from the schist area immediately upstream from this claim.

The fact that no notable concentrations of placer gold have been found along the remainder of the valley, although it is clear that a large quantity of the high gravel has been eroded and concentrated by Eva Creek, seems to point to the conclusion that the old gravels carry very little if any gold in this drainage basin.

WINTER AND MARGUERITE CREEKS.

Prospecting for placer gold has been done at a number of points on the headwater streams of California Creek that drain the flanks of Jumbo Dome, the prominent mountain 4,500 feet high that occupies an isolated position near the head of the valley. The streams that have been examined most thoroughly are Winter Creek, which drains the northeastern flanks of Jumbo Dome, and Marguerite Creek, which flows along the southern and western flanks of this mountain. Many old prospect holes may be observed along the courses of these streams, but although the stream gravels appear to have been thoroughly prospected there are no data at hand upon which to base a statement as to the presence or distribution of placer gold in their basins.

UPPER TOTATLANIKA CREEK.

GENERAL FEATURES.

The upper Totatlanika lies from 5 to 7 miles east of California Creek and flows northward across the foothill belt in general parallelism with that stream. The major features of the valley comprise three basin areas separated by two belts of mountainous country across which the valley is eroded in the form of canyons. These features of relief are similar to those that characterize the valley of California Creek and in fact are their eastward continuations, although there are differences of detail in the two valleys. Some of these differences may be noted as follows:

A minor canyon, the Daniel Creek canyon, is eroded across an area of schist for about a mile in the lower or northernmost basin of the valley, about 2 miles below Murphy Canyon, which separates the lower basin from the middle basin.

The middle basin of the upper Totatlanika differs from the corresponding basin of California Creek in that it is eroded chiefly in schistose rocks, the lignite-bearing sediments that seem to have formerly overlain the schist of this basin having been eroded away in greater part.

The middle basin is separated from the upper or headwater basin of the Totatlanika by a rugged mountainous belt whose summits reach altitudes of 3,500 to 4,000 feet. These mountains are composed largely of igneous rocks intruded in schist. In some respects this highland belt is similar to the Jumbo Dome area, to the west, with which it is topographically connected; but it is different in that all the larger streams have eroded deep gorges across the mountains. Homestake Creek, the westernmost headwater tributary of the Totatlanika, has cut a deep and narrow canyon through this barrier between the upper and middle basins. The main Totatlanika also has eroded a deep gorge across these mountains from southeast to northwest for a distance of several miles above the mouth of Homestake Creek, and two large southern tributaries in this section, named Thistle and Davis creeks, have likewise eroded deep gorge valleys across the mountains along the lower mile of their courses and thus maintained their adjustment with the down cutting of the valley.

The headwater basin of the Totatlanika is in reality a part of the same belt of lowland in which the valley of Hoseanna Creek, to the west, is deeply intrenched. Although these contiguous basins are separated topographically by a broad transverse divide they are nevertheless so closely related that they may be considered to form one continuous lowland; and geologically they are actually a continuous belt, for the lignite-bearing sediments that occupy the greater parts of both areas extend for 20 miles from east to west through the two basins. The Totatlanika headwater basin is 5 to 6 miles wide from north to south and about 8 miles from east to west. In general aspect its surface is broadly undulating, but in detail it is somewhat dissected transversely by the headwater streams that flow across it from south to north. These streams have intrenched their courses to a depth of several hundred feet below the interstream areas. The chief headwaters of the Totatlanika have their sources on the steep flanks of mountains of schistose rocks that bound the basin on the south. The summits of these mountains stand at altitudes of 5,000 to 6,000 feet, or about 3,000 feet above the surface of the basin area. These mountains may be considered to be an outlier of the Alaska Range in this locality, although to the west, where they form the divide between Hoseanna and Healy creeks, their altitude decreases to 3,000 feet.

The discovery of placer gold in the Totatlanika valley is stated to have been made at the mouth of McCuen Gulch in February,

1905. Since that time most of the placer gold produced in the Nenana district has been mined from the foothill section of this valley at several localities along the main stream and on several of its tributaries. Most of the gold has been obtained from Homestake and July creeks, but a considerable amount has also been mined from the gravels of the main stream in the middle basin of the valley, especially in the lower part of this basin, near the head of Murphy Canyon.

It is reported that gold "colors" may be obtained at almost any point in the stream gravels along the present bed of upper Totatlanika Creek from its junction with California Creek to a point above McCuen Gulch, or for a distance of about 20 miles. Placer claims have been staked throughout this distance during the last 10 years, but mining has been done upon only a few of these claims in the middle basin, between the head of Murphy Canyon and a point about half a mile above the mouth of Homestake Creek. In this section the conditions for the concentration of placer gold in commercial amounts seem to be more favorable than elsewhere in the valley.

In the lower basin, through which the Totatlanika flows for about 10 miles of its course, large tracts of flood-plain gravels have been held under location for a number of years, in the form of association-group claims, in the belief that the deposits might be valuable for dredge mining. There are considerable areas of stream gravels in this lower basin that may be easily mined by this method, but no data are at hand regarding the amount of placer gold that may be contained in the deposits, and up to the present time no attempt has been made to prospect the ground with dredge mining in view. The only mining that has been done in the lower basin is on a tributary named Daniel Creek.

DANIEL CREEK.

Daniel Creek flows into the Totatlanika from the southwest at a point about 2½ miles downstream from the lower end of Murphy Canyon. It is a stream of comparatively small volume, about 4 miles long, whose valley may be divided into three sections—an upper one comprising two large headwater gulches; a rather open basin area along the middle of the stream, about 1 mile in length; and a narrow lower section intrenched to a depth of several hundred feet, also about 1 mile in length.

The two headwater branches of Daniel Creek have their sources high on the northern flanks of the mountain belt of schistose rocks that separates the lower and middle basins of the main valley. Both of these branches have eroded deep gulches into the schist along the upper mile of their courses, but so far as known this erosion has not resulted in the concentration of placer gold in the gravels of these gulches.

The lower courses of the two headwater branches of Daniel Creek flow into the middle basin of the valley and join in its central part. This basin is eroded chiefly in slightly consolidated lignitic sediments that are overlain by the Nenana gravel about the borders of the basin. Remnants of this gravel also rest on the lower flanks of the schist spurs that bound the upper part of the basin and occupy considerable areas on the higher slopes of the valley below the middle basin. It seems evident that a considerable amount of the Nenana gravel, together with some lignitic sediments that underlie it in the middle basin, has been eroded away during the development of the Daniel Creek valley. From the junction of the headwater branches of Daniel Creek to its mouth, a distance of about 2 miles, the stream has cut below the base of these sedimentary deposits and intrenched its course to a depth of 100 feet or more into harder and much older schist that forms the basement upon which the slightly consolidated sediments rest.

For half a mile below the junction of the headwater branches of Daniel Creek its flood plain has a width of 300 to 600 feet and consists of gravels about 10 feet thick that rest on schist bedrock. At the lower end of the middle basin the stream flows for about an eighth of a mile through a narrow gorge which is formed by spurs of schist bedrock along the lower valley slopes. Below this contracted section the valley floor again broadens to a width of 200 to 400 feet, which it maintains to a point within about a quarter of a mile of the mouth of the stream. The lower quarter mile of Daniel Creek is confined in a narrow rocky gorge several hundred feet in depth, eroded in schistose rocks. The Totatlanika also in this part of its course flows in a canyon, eroded in schist to a depth of several hundred feet, that extends for some distance above and below the mouth of Daniel Creek.

The basin and gorge sections of the Daniel Creek valley are directly due to the unequal resistance to erosion offered by the slightly consolidated sediments and the hard schistose rocks that the stream has encountered along its course.

Placer claims have been located along Daniel Creek since 1905, as on most of the other streams in the Totatlanika Valley, but mining operations have been undertaken upon it only during the last three years.

The most valuable claims extend along the lower mile of the creek and are four in number, each of the regulation length of a quarter of a mile. The claim at the mouth of the creek is designated Discovery claim and the other as Nos. 1, 2, and 3 above Discovery. These four claims cover the more or less constricted section of the valley that extends from the basin area along its middle course to its mouth.

The middle basin is also under placer location, but no mining has been done in that area up to the present time.

Along the lower mile of its course Daniel Creek has eroded to a depth of about 150 feet into the schistose rocks that underlie a mantle of Nenana gravel several hundred feet thick. Thus the steep slopes of this narrow section of the valley are of schist in their lower parts and of gravel in their upper parts. Considerable quantities of gravel loosened from the upper slopes have slumped down and partly obscured the schist bedrock of the lower slopes along some parts of the valley, but along other parts the schist bedrock is well exposed, and several spurs of schist project into the valley alternately from opposite sides along claims 1, 2, and 3 above Discovery.

Between these bedrock spurs there are along both sides of the creek narrow sloping benches that range in width from 50 to 150 feet and stand from 5 to 20 feet above the stream. These benches are composed of a mixture of blocks and smaller slabs of schist, cobbles, and gravels derived from the higher slopes, and considerable earthy detritus. This material is very poorly washed except that along the immediate bed of the stream. As a whole this detritus appears to be more a mixture of material that has accumulated from the valley slopes by sliding and creeping than a normal stream deposit.

The greater part of the alluvium along the valley floor does not contain permanent frost. However, there are small areas in which the results of seasonal freezing survive well into the following summer, and it may be that some of the deeper alluvium is more or less permanently frozen.

The first mining on Daniel Creek is reported to have been done in 1914 by two men on the lower end of claim No. 1 above Discovery, at the head of the gorge through which the stream discharges into the Totatlanika from the wider part of its valley covered by claims Nos. 1, 2, and 3 above Discovery. The work on this claim consisted of a small automatic dam by means of which a cut about 40 feet wide and 200 feet long was groundsluiced down to bedrock through about 4 feet of gravels. It is reported that about $1,500 worth of gold was mined from this cut. Some parts of the cut yielded $70 worth of gold to the box length—that is an area 12 feet long by 14 feet wide, comprising about 168 square feet.

During 1916 three men mined on the lower part of claim No. 3 above Discovery, about half a mile above the former workings. The first dam they built was destroyed by a flood in the middle of June, and the second one had been in operation only a few days at the time of the writer's visit, early in July. At that time a cut from 20 to 40 feet in width and about 300 feet in length had been partly groundsluiced, but the gravels were not yet sufficiently concentrated on bedrock for shoveling into the sluice boxes. During the first week in July the volume of Daniel Creek was sufficient to fill the pond above the dam only three times an hour, and the miners were hoping for enough rainfall to increase the stream flow to a volume that would fill the pond at 5-minute intervals in order that they might expedite their work. The production of gold from this operation was not learned.

So far as was learned the placer gold of Daniel Creek consists chiefly of rather fine particles that are somewhat rounded or worn. The evidence at hand seems to indicate that placer gold in commercial amounts is restricted to the lower mile of the valley. As the Nenana gravel in the upper part of the valley does not appear to have yielded placer gold in notable amounts, and as there is no reason for believing that the same gravel along the lower mile of the valley is more auriferous than elsewhere in this locality, it may be inferred that the schist bedrock along the lower mile of the valley is a probable source for the placer gold that now occurs along that section of Daniel Creek. No convincing evidence, however, was obtained as to the gold-bearing character of the particular belt of schistose rocks that has been eroded by the stream, although these rocks were observed to be mineralized to some extent with vein quartz.

PLACERS OF THE MIDDLE BASIN.

HISTORY OF MINING.

Placer gold has been mined from the stream gravels of the upper Totatlanika in its middle basin at several localities between the head of Murphy Canyon and a point about half a mile above the mouth of Homestake Creek, a distance of about 3 miles. The gravels along this section of the stream are reported to be gold bearing throughout, but the better concentrations appear to be somewhat localized. Most of the mining has been done in the lower part of the basin on three claims that cover the approach and entrance of the stream into Murphy Canyon. These claims are designated Discovery claim and Nos. 1 and 2 below Discovery.

Gold was first found on Discovery claim in March, 1905, and some mining was done on this ground during the summer of that year. In 1906 the chief mining was done on claim No. 1 below Discovery. No mining of any consequence has been done on claim No. 2 below Discovery, but it is stated that the gravels on this claim contain good prospects. Although these claims have not been actively mined each year since their location, they are still in the possession of the discoverers, and considerable work has been done upon them from time to time in order to retain them until conditions for fuller development become more favorable, especially in the matter of transportation of supplies to the district. The combined gold production from these three claims up to the present time is estimated to be worth about $15,000.

The comparatively large volume of Totatlanika Creek during most seasons of the year makes the problem of mining the gravels in the bed of the stream more one of controlling the water than of obtaining an adequate supply for washing the gravels. The grade of the stream is about 100 feet to the mile in this part of its valley, and the quantity of water varies greatly. Dams with flood gates have been built across the stream to regulate the flow and facilitate groundsluicing; and these have been supplemented by wing dams to divert the stream to one side of its flood plain while the other side was being mined.

From time to time open-cut mining has been done on the bars and low flood-plain gravel benches of the Totatlanika at a number of points between July Creek and Homestake Creek, but none of these operations have led to extensive developments, because the control of the main stream is difficult. For example, two men worked at a point about a mile above July Creek during the early part of the summer of 1916 until their workings were washed out by a flood. In the later part of the summer one man was mining bar gravels in the main stream bed about half a mile above the mouth of Homestake Creek. The gravels at this locality were about 3 feet in depth, and the bedrock consists of much jointed and contorted slate. The gold obtained is rather fine and much flattened. The yield was stated to be the equivalent of current wages, or about $6 a day to the man.

BEDROCK AND MINERALIZATION.

The middle basin of the upper Totatlanika is eroded chiefly in schistose rocks. Although there is evidence that a large part of this basin was formerly occupied by lignitic sediments overlain by the Nenana gravel, such as are now present in most of the other valley basins of the district, only small remnants of these sediments still remain in this part of the Totatlanika Valley.

The schists comprise rocks of both igneous and sedimentary origin. The igneous schists are feldspathic and most of them are porphyritic. The sedimentary schists might in large part be called slates and are more or less carbonaceous. These black slaty rocks occupy the greater part of the southern half of the basin, where they crop out across the valley in several successive belts that strike northwest and dip 40°-50° NE. The feldspathic schists occupy the northern half of the basin and appear to overlie the sedimentary schists. Both types of schist have reached about the same degree of metamorphism, and both are intruded by dikes of siliceous composition and granular character. These dikes likewise show the effects of considerable alteration, being strongly sheared and recrystallized to a degree that indicates they were intruded into the country rocks before the end of the regional metamorphism.

Quartz veins are abundant in both kinds of schist but particularly in the slates, and the sheared dikes also contain vein quartz in many places. The siliceous dikes intruded into the schists are probably the primary agency of gold mineralization in this basin, and probably also the greater part of the placer gold in the present stream gravels has been derived from the schists through erosion since the lignitic sediments and high gravels were removed from the basin.

CHARACTER OF THE DEPOSITS.

The width of the stream gravels on the three claims in the lower part of the middle basin ranges from about 400 feet on Discovery claim to about 100 feet at the lower end of claim No. 2 below Discovery, where the stream is crowded between the converging walls of Murphy Canyon. The gravels range in thickness from 3 to 6 feet and consist of typical stream-bar material throughout the width and length of the flood plain. They are rather coarse, containing many cobbles as much as 6 inches in diameter and a number of boulders from 1 to 2 feet in greater dimensions. The percentage of small pebbles and sand is not large. Altogether the deposits are cleanly washed and show the effects of reworking or shifting from one part of the flood plain to another due to the fluctuations in the stream flow.

The bedrock is of schist, the surface of which is rather irregular and blocky in character. Many of the joint crevices in this schist are rather open, and the particles of gold penetrate some of them to a depth of 2 or 3 feet.

Practically no permanent frost is present in the stream-washed deposits, probably because there is an abundant and free percolation of water through them during the greater part of the year.

JULY CREEK.

An instance of the close relation between gold mineralization and the dikes that intrude the schists is disclosed by mining operations on July Creek, one of the streams of the middle basin. July Creek is a small stream, about 2 miles long, that discharges into the Totatlanika from the western slopes of the valley about half a mile above the head of Murphy Canyon, or approximately at the boundary line between Discovery claim and claim No. 1 below Discovery on the main stream. The valley of this tributary is eroded in schists and along the lower half mile of its course is narrow and bounded by steep walls 100 to 150 feet in height.

At a point about a quarter of a mile above the mouth of July Creek the schists are intruded by a dike that trends across the gulch in a northeasterly direction. The stream gravels along the creek from this dike down to the mouth have been found to contain placer gold in sufficient quantity to make mining profitable, but it is significant that practically no placer gold whatever has been found in the gravels of the gulch above this dike. Although lode gold has not been observed in this dike or the schists that it intrudes, the evidence points to the conclusion that the dike is the mineralizing agency on which the placer gold along the lower part of July Creek is dependent, or, at least, that the gold has a bedrock source in the schists near the dike rather than in the Nenana gravel that formerly overlay the schists. For if even part of the placer gold of July Creek was derived by reconcentration from deposits of the Nenana gravel that formerly overlay the schists some gold should still remain in the stream gravels above the dike, as there is evidence that the Nenana gravel was formerly present in the area now drained by upper July Creek. The sharp upstream limit in the distribution of placer gold along July Creek at the position of the dike therefore seems to indicate that this dike is closely connected with the mineralization in the schists from which the placer gold is derived.

It is reported that much of the gold mined from July Creek was rough, and that some of it was attached to vein quartz. The largest nugget mined was worth about $25.

As the gold-bearing gravels on July Creek are limited in extent almost to one narrow gulch claim, they were mined out in about two years by pick and shovel. Most of this mining was done during the summers of 1910 and 1911. Along some parts of the claim the gravels yielded $200 worth of gold to the box length (168 square feet). A total production of fully $10,000 worth of gold is reported to have been obtained from this claim.

It is highly probable that placer gold has been carried from July Creek, along with its gravels, and deposited in the flood plain of the Totatlanika, especially on claim No. 1 below Discovery, which extends downstream from the mouth of July Creek. In fact, it seems likely that July Creek may be the source of much of the placer gold that occurs in the gravels of the main stream for some distance below it, although some of the gold may have been brought down the Totatlanika from the region above July Creek, and some may be derived from local bedrock sources below July Creek, for the Totatlanika has eroded this part of its valley to a considerable depth into schistose rocks. The mineralized belt of lower July Creek may extend across the valley of the Totatlanika, for the dike on July Creek trends in a northeasterly direction, although its outcrop has not been traced to the main stream. The schists along this part of the Totatlanika contain many quartz veins.

HOMESTAKE CREEK.

Homestake Creek, which has been the most productive placer-gold stream in the Nenana district up to the present time, is the westernmost headwater tributary of the Totatlanika from its upper basin and discharges into the middle basin of the main valley, about 2 miles above July Creek, through a deep canyon eroded across the mountainous belt that separates these two basins. The total length of Homestake Creek is about 5 miles, but the upper 3 miles of its course is locally known as Platte Creek and the name Homestake Creek is generally applied to the lower 2 miles of the stream, or to that part which flows through the canyon. The upper 3 miles of the valley shows a marked contrast in topographic character to the lower 2 miles in that it is a part of the broad undulating headwater basin of the Totatlanika eroded in the soft lignite-bearing sediments and overlying gravels.

The volume of Homestake Creek is comparatively small and seems particularly so in comparison with the canyon along its lower course, which is about 1 mile long and is eroded to a depth of about 1,000 feet. There may be some doubt that the stream in its present form is to be credited with the amount of erosion represented by this canyon, for the catchment area of Homestake Creek in the upper basin of the Totatlanika is limited to about 5 square miles. It is probable that formerly the drainage area was much more extensive.

The highland belt that separates the middle and upper basins of the Totatlanika is made up chiefly of massive igneous rocks that are intruded into schists. These intrusive rocks occupy an area about 1½ miles wide from north to south and 5 miles long from east to west and extend from a point 2 miles west of Homestake Creek to a point about 3 miles east of that stream. Two other tributaries of the Totatlanika, Thistle and Davis creeks, situated about 1 and 2 miles east of Homestake Creek respectively, have also eroded deep gorges in these rocks from south to north. The valleys of these three streams dissect the igneous mass into a group of prominent mountains, whose summits stand at altitudes ranging from 3,000 to nearly 4,000 feet.

The igneous rocks that form most of these mountains are andesitic but contain a considerable amount of quartz and might properly be termed dacites. These rocks show considerable decomposition and on the surface have a general dark reddish-brown color due to the development of iron oxides through weathering.

No particular evidence of quartz vein mineralization was observed in these massive igneous rocks, but the carbonaceous slates along the northern border of the intrusive mass in the middle basin of the Totatlanika contain a considerable number of small quartz veins, and some evidence of vein-quartz mineralization was also observed in a narrow belt of deeply disintegrated schist that crops out along the southern border of the intrusive rocks at the head of Homestake Creek canyon, especially along the course of Fox Gulch, a short tributary from the west. The stream gravels along the lower part of Fox Gulch and along Homestake Creek for half a mile below the mouth of this tributary, in the entrance to the canyon, are the richest gold placers of the valley, and their intimate association with the contact zone of schist that forms the bedrock of this part of the valley suggests that the placer gold may be derived from the schist.

Placer gold was discovered on Homestake Creek in the summer of 1905, and during that year eight or nine claims were located along the lower 2 miles of the stream from its mouth to a point a short distance above Fox Gulch. One or more claims were also located on the lower course of Fox Gulch. Discovery claim is about a mile above the mouth of the creek, in the middle of the canyon, and the other claims are numbered consecutively up and down the stream. These claims cover all that part of Homestake Creek valley that is eroded in hard igneous or schistose bedrock, and good prospects of placer gold may be obtained from the stream gravels of practically every claim.

In general the stream deposits along the lower 1½ miles of the valley consist of rather coarse, poorly assorted gravels mixed with many large boulders and considerable quantities of cobbles, although in several small areas where the valley bottom widens to 300 or 400 feet the gravels are finer and better assorted than elsewhere. The stream bed along the narrowest part of the canyon, from one-half to 1½ miles above its mouth, contains numerous large boulders and angular blocks of igneous rock derived directly from the steep valley slopes, which are mantled with thick accumulations of talus. The upper part of this canyon is more open in form, and the stream deposits in it are much finer than those below, consisting chiefly of finely broken up schistose rocks that contain relatively few large boulders, although the deposits include some well-rounded pebbles of the Nenana gravel derived from the headwater area above. The bedrock of this part of the valley consists chiefly of schist, and it is evident that a large part of the gravels are of local derivation.

Placer mining has been done on Homestake Creek since 1906. Most of the mining has been done on the four claims above Discovery claim and the claim on lower Fox Gulch, and nearly all of this ground is considered to be now worked out, although it is probable that considerable gold still remains in the gravels.

An inadequate supply of water has limited all operations to ordinary open-cut pick and shovel work with small sluice boxes and has prevented the development of the ground in a systematic manner. The flow of water from the small headwater area of Homestake Creek is ordinarily so scanty that it is necessary to pond the stream by means of dams back of which the water is accumulated at night in order to obtain sufficient water to wash the gravels the next day. The disintegrated character of the schistose gravels and the fact that they contain considerable finer detritus and are not much compacted facilitates mining with the small quantity of water available, which rarely exceeds a full sluice head except during periods of more than average rainfall.

The gravels are from 3 to 6 feet in thickness, and most of the gold occurs in their lower part and in the upper foot of decomposed schist bedrock. It is reported that yields of $200 to $250 to the box length have not been uncommon on some of the ground. This is the equivalent of $5 to $7 a cubic yard.

The period of greatest activity in mining on Homestake Creek was from 1906 to 1909, during which more or less work was done on all the claims from Discovery claim, in the canyon, upstream to and a short distance above Fox Gulch and on the lowermost claim on that tributary. Since 1910 the chief work has been done on the claim that extends above and below the mouth of Fox Gulch, and in 1916 two men were engaged in mining on the lower part of this claim in some low bench gravels along the west side of the valley bottom.

It is estimated that about $80,000 worth of gold has been produced from the placer claims on Homestake Creek that extend upstream from Discovery claim to and including Fox Gulch. A few thousand dollars' worth of gold has also been mined from the claims on the lower part of Homestake Creek below the canyon. In 1907 one man worked on claim "No. 4 below," just above the mouth of the creek, and in 1916 one man was engaged in mining on this claim during the later part of the summer.

McCUEN GULCH.

McCuen Gulch is on the north side of the upper Totatlanika about 5 miles above the mouth of Homestake Creek. It is about 1½ miles long and carries a very small quantity of water except during periods of heavy rainfall, and even at such times it drains quickly because of its steep grade, which is more than 1,500 feet between its mouth and source. As a whole the gulch is not very deeply dissected into the mountain slope along its upper course, but its lower quarter of a mile is somewhat sharply intrenched to a depth of about 100 feet across a sloping bedrock bench that marks a former flood plain of the valley of the upper Totatlanika. It is along this lower section of the gulch that placer gold has been mined.

The mountain slopes in which McCuen Gulch is eroded are made up of schistose rocks that are intruded by one or more dikes near the head of the gulch. One of these dikes consists of siliceous granitic rock and is sheared, like other dikes that are intruded into the schists at many localities throughout the district. Some small veins of iron-stained quartz occur in the schist in the vicinity of the sheared dike, and the dike rock itself contains some veinlets of quartz.

Placer gold was first found in the basin of the Totatlanika at the mouth of McCuen Gulch in February, 1905, and this discovery caused the excitement that resulted in the location of placer claims on practically all the streams in the district during the following summer and autumn. No information is at hand regarding the amount of gold that has been mined from this gulch, but it probably does not exceed $2,000. It is reported that one man mined several hundred dollars' worth of gold from this gulch in 1915. In August, 1916, one man was engaged in groundsluicing a small open cut with the intention of mining before the season closed.

All the mining on McCuen Gulch has been done within 1,500 feet of its mouth. In fact, it is only along this section of the stream that there is much alluvium in the gulch. The alluvial deposit is from 5 to 10 feet in thickness and 50 to 100 feet in width and consists of a relatively small proportion of well-rounded gravel mixed with numerous blocks and slabs of schist and considerable finely divided schist detritus. As a whole the material is poorly assorted and shows the lack of sufficient water in the stream to wash and concentrate the gravels thoroughly.

Although this gulch has yielded little placer gold, it is of interest in that the gold appears to be derived from a local bedrock source in mineralized schistose rocks rather than by reconcentration from the Nenana gravel.

TATLANIKA AND GOLD KING CREEKS.

LOCATION AND GENERAL FEATURES.

Tatlanika Creek lies about 10 miles and Gold King Creek about 16 miles east of the upper course of Totatlanika Creek. These two streams are of similar character and together drain the greater part of the foothill belt between the basin of the Totatlanika and the valley of Wood River. Their valleys extend from south to north across the foothill belt, a distance of about 20 miles, and are eroded to depths of 1,000 to more than 1,500 feet below the adjacent broad ridges. These valleys do not present the diversity of relief that characterizes the foothill basin of Totatlanika Creek, because they are eroded in thick and widespread deposits of the Nenana gravel, except in their headwater sections and in a short canyon on the lower Tatlanika.

The general geology and gold placers of Tatlanika and Gold King creeks were examined by Prindle[1] in 1906 and by Capps[2] in 1910. Since then these valleys have not been visited by members of the Geological Survey, but placer mining has been continued on them up to the present time at several localities. The writer obtained a few notes regarding these later developments from miners on the Totatlanika who are familiar with the district.

TATLANIKA CREEK.

Practically all the placer mining in the valley of Tatlanika Creek has been done on three tributaries, named, in upstream order, Hearst, Roosevelt, and Grubstake creeks, which discharge into the main stream from the east along the middle part of its course. More or less mining has been done on these streams since 1905, but the most continuous work has been done on Grubstake Creek, where from two to six men have been employed each year. Roosevelt Creek appears to rank next to Grubstake Creek in importance, and Hearst Creek has been the least productive of the three streams. It is reported that four men were engaged in mining on Grubstake Creek and one man on Roosevelt Creek in 1916.

Hearst, Roosevelt, and Grubstake creeks are from 2 to 4 miles long and of comparatively small volume. They are streams of like character, especially with regard to the geology of the areas they drain and the conditions under which the placer gold occurs along their courses. Their sources are fully 1,000 feet above their mouths, on the higher slopes of a broad ridge of the Nenana gravel that separates the valley of the Tatlanika from that of Gold King Creek, to the east. The upper halves of the valleys of all three of these tributaries are eroded in the thick Nenana gravel, but the lower courses, from 1 to 2 miles above their mouths, are eroded below the base of the Nenana gravel to a depth of 100 feet or more in semiconsolidated sediments composed of interbedded clays, sands, and gravels, with some thin beds of lignite. These underlying deposits are very similar in general composition to the thick lignite-bearing sediments that occupy large areas in the basins of Totatlanika, Hoseanna, and Healy creeks and elsewhere in the region, and on this basis they would be considered to be of Eocene age. However, fossil plant remains that have been obtained from these sediments near the mouth of Roosevelt Creek seem to indicate that they may be younger than the typical lignite-bearing formation of the region.

The chief points of interest with regard to the plant-bearing clays, sands, and gravels in the Tatlanika Valley are that these sediments form the bedrock upon which the placer gold of Hearst, Roosevelt, and Grubstake creeks is now concentrated; that the thick Nenana gravel overlies these sediments; and that the stratigraphic relations of the Nenana gravel with the semiconsolidated sediments upon which it rests appear to be similar to those exhibited in the valley of lower Healy Creek (see pp. 372–373), where about 500 feet of sandy shales with cross-bedded sands and gravels containing some lignitic layers underlie the Nenana gravel and overlie the typical lignite-bearing formation of the region. In both localities there is strong evidence that the placer gold in the present stream gravels is derived by reconcentration from older placers in the Nenana gravel and that these older placers are most probably in the basal part of the formation.

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[1] Prindle, L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, pp. 210–212, 1907.

[2] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 47–51, 1912.

The placer gold on Hearst, Roosevelt, and Grubstake creeks occurs chiefly in about 2 feet of the present stream gravels that rest on a bedrock composed of interbedded clays, sands, and gravels, with some semiconsolidated lignitic layers. This bedrock is overlain by the thick mass of the Nenana gravel in which the valleys are chiefly eroded.

A large area along the flood plain of Tatlanika Creek has been held under placer locations in the form of association-group claims of 160 acres each for the last 10 years. This tract of claims is reported to extend along the bottom of the valley for a distance of 10 miles or more, from a point above the mouth of Grubstake Creek downstream to the short canyon eroded in hard schist about 7 miles below the mouth of Hearst Creek. Along this section of its course Tatlanika Creek has cut a valley floor from one-fourth to three-fourths of a mile wide and distributed over it a large quantity of reworked gravels derived from the thick Nenana gravel. It is reported that the bar gravels along this section of the stream, together with low bench gravels, contain prospects of placer gold, and that the prospecting of these deposits with drills was to be undertaken during 1917. If these gravels prove to contain profitable amounts of placer gold they could probably be easily mined by means of dredges, for they apparently occur under geologic conditions similar to those that characterize the placers of Hearst, Roosevelt, and Grubstake creeks as described. It is also probable that some of the placer gold contained in the gravels of the main stream may be derived from these three tributaries.

GOLD KING CREEK.

Placer gold has been mined from a few claims on Gold King Creek since 1903. Prindle reports that about 12 men were working on this stream in 1906, and Capps states that claims 19 and 21 below

Discovery were under operation in 1910. It is reported that two persons were mining on this stream in 1916. All this mining has been done in the bed of the main creek at localities where the present reworked stream gravels are from 4 to 8 feet thick and rest on a bedrock of clay. Some of the gold is recovered from the gravels, and some from the soft clay bedrock upon which it is concentrated. All the mining has been done by open-cut pick and shovel methods.

The conditions under which placer gold occurs in Gold King and Tatlanika creeks appear to be similar. The valley of Gold King Creek differs from that of Tatlanika Creek in that its bottom has not been widened so much by lateral erosion. This valley is V-shaped in cross section. Its tributaries have not eroded flood plains back from the main stream like those of Hearst, Roosevelt, and Grubstake creeks in the Tatlanika basin.

It appears as if the clay bedrock along the narrow bed of Gold King Creek, upon which the placer gold is concentrated at the localities where mining is being done, may be the equivalent of the formation upon which placer gold is concentrated in the valley of Tatlanika Creek, the difference between the two valleys being that Gold King Creek has barely eroded its bed down to or a few feet below the base of the thick Nenana gravel, whereas Tatlanika Creek has eroded its valley floor to a depth of 100 feet or more below the Nenana gravel and laid bare a considerable area of the underlying formation by lateral erosion.

A large hydraulic mining enterprise on Gold King Creek that had been under construction for several years and was nearly ready for operation in 1910, at the time of Capps's visit, is reported to have been abandoned in the later part of that summer after a trial run of only a few days. This project comprised a system of ditches about 11 miles in extent that was designed to convey 3,000 miner's inches of water from the upper part of Gold King Creek to a point on the eastern slopes of the valley, where it was to be delivered to a pipe line under a head of 700 feet. The intention was to mine the thick Nenana gravel on the lower slopes of the valley, but apparently no systematic prospecting of the gravels to be mined was done before the project was undertaken.

SUGGESTIONS TO PROSPECTORS.

As has been pointed out with reference to the gold placers of Home, Alaska, and French creeks, tributaries of Healy Creek (see pp. 376–379), there are no positive data at hand as to whether the placer gold supposed to be contained in the Nenana gravel is confined to one or a few particular beds or horizons in that formation, or is somewhat widely distributed throughout its thickness. The evidence furnished by the distribution of placer gold in the present stream gravels of

French, Alaska, and Home creeks, however, affords a basis for the surmise that this gold has its chief source in the lower 500 feet of the Nenana gravel, whose thickness in Healy Creek valley is fully 2,000 feet and in the valleys of Tatlanika and Gold King creeks at least 1,500 feet.

So far as known, no comprehensive attempt has been made to prospect for gold in the Nenana gravel itself. As pointed out by Capps,[1] if such work is undertaken, it is essential that tunnels should be driven far enough into the deposits to reach undisturbed beds that have certainly not been enriched by gold from some outside source. With little doubt it is most advisable to undertake such prospecting at or near the base of the Nenana gravel rather than higher in the section.

Another suggestion to be borne in mind is that made by Prindle[2] with reference to the placers of Tatlanika Valley, which also applies to the deposits in the valley of Gold King Creek:

> A point to be emphasized is that the soft clays and sands which form the bedrock are just as truly bedrock to the stream gravels that overlie them and carry the gold as if they were hard rock. A thickness of several hundred feet of these unconsolidated deposits may overlie the hard bedrock, and any attempt to sink through them to the solid formation would be not only a most difficult task, but, inasmuch as the only run of gold known overlies them, would be in all probability useless.

This suggestion is particularly applicable to the drilling operations which, according to report, are to be undertaken in the main valley of the Tatlanika.

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[1] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, p. 50, 1912.

[2] Prindle, L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, p. 211, 1907.

LODE MINING IN THE FAIRBANKS DISTRICT.

By J. B. **Mertie**, Jr.

INTRODUCTION.

Gold lode mining in the Fairbanks district continued in 1916, with a small production. The cost of power and supplies has increased so greatly that most of the operators have either closed their mines or are operating on a scale little more extensive than prospecting. Most of the operators having high-grade gold ore do not care to continue work under present conditions, which allow them only small profits, and the owners of lower-grade ore can not afford to operate at all. The general policy of all concerned in the gold mines is to await the coming of the Government railroad to Fairbanks, the expectation being that this will effect a general decrease in operating costs. Cheaper power is perhaps the most urgent need of the lode mines, and the Government railroad, by making available the coal resources of the Nenana and Matanuska coal fields, should help materially. A central power plant, utilizing perhaps the low-grade Nenana coal, may prove the ultimate solution of the difficulty.

Eight gold lode mines, however, were operated in the Fairbanks district in 1916, producing gold valued at nearly $40,000. This is the smallest yearly production of lode gold and silver in the district since 1910, when the lodes were just beginning to be opened.

Lode gold and silver produced in the Fairbanks district, 1910–1916.

Year.	Total quantity of crude ore (tons).	Gold.		Silver.	
		Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1910	148	841.19	$17,339	106	$57
1911	875	3,103.02	64,145	582	308
1912	4,708	9,416.54	194,657	1,578	971
1913	12,237	16,904.98	349,457	4,124	2,491
1914	6,526	10,904.75	225,421	2,209	1,222
1915	5,845	10,534.91	217,776	1,796	910
1916	1,111	1,904.81	39,370	140	92
	31,450	53,610.20	1,108,221	10,535	6,051

The beginning of antimony mining in the Fairbanks district, the mining developments in 1915, and the occurrence, distribution, and character of the ores have been described by Brooks.[1] The decline in the price of antimony early in the summer of 1916 led to the closing of most of the antimony mines in the district, only one being in operation at the time of the writer's visit in August. Notwithstanding this fact, the production of antimony was materially increased over that of 1915.

One silver-lead lode was operated in 1916.

Three tungsten mines were operated, producing about 16½ tons of scheelite concentrates. Prospecting for tungsten lodes was also actively carried on.

Plate XVIII shows the locations of the lode mines and prospects so far discovered in the Fairbanks district.

GOLD LODES.

The following report is intended only as an outline of progress made in lode mining in the Fairbanks district and not as a comprehensive description of all the lodes. Reference is made only to the producing mines and to some others that are being actively prospected. In a later report the writer will present generalizations based on a study of the lode systems and their mineralization and will include the results of petrographic and metallographic studies of the ores.

The eight gold lode mines that were worked in 1916 were that of Crites & Feldman, on Moose Creek; the Mizpah, on Fairbanks Creek; the Homestake, at the head of Wolf Creek; the Mohawk, at the head of Eldorado Creek; that of Nars, Anderson & Gibbs, between Moose and Too Much Gold creeks; the Ohio group (Gilmore & Stevens), on Fairbanks Creek; the Center Star, on Skoogy Gulch, tributary to Twin Creek; and the St. Paul, at the head of Eva Creek.

CRITES & FELDMAN.

The Crites & Feldman mine, though operating on a rather small scale at present, is the largest producer of lode gold in the district. The work being done in 1916 was really in the nature of prospecting. The old tunnel on the Helen S. claim, described by Chapin,[2] from which the gold ore has been taken in the past, has been temporarily abandoned, and a new tunnel has been started on the Hiyu claim. The new tunnel is higher up the west slope of Moose Creek and is being driven along the continuation of the vein system, to determine the gold content of the veins, and in this way to learn whether it will pay to extend the old tunnel farther west.

The new tunnel was driven 350 feet on the gold quartz vein previously mined at the old tunnel. At this points a split in the vein

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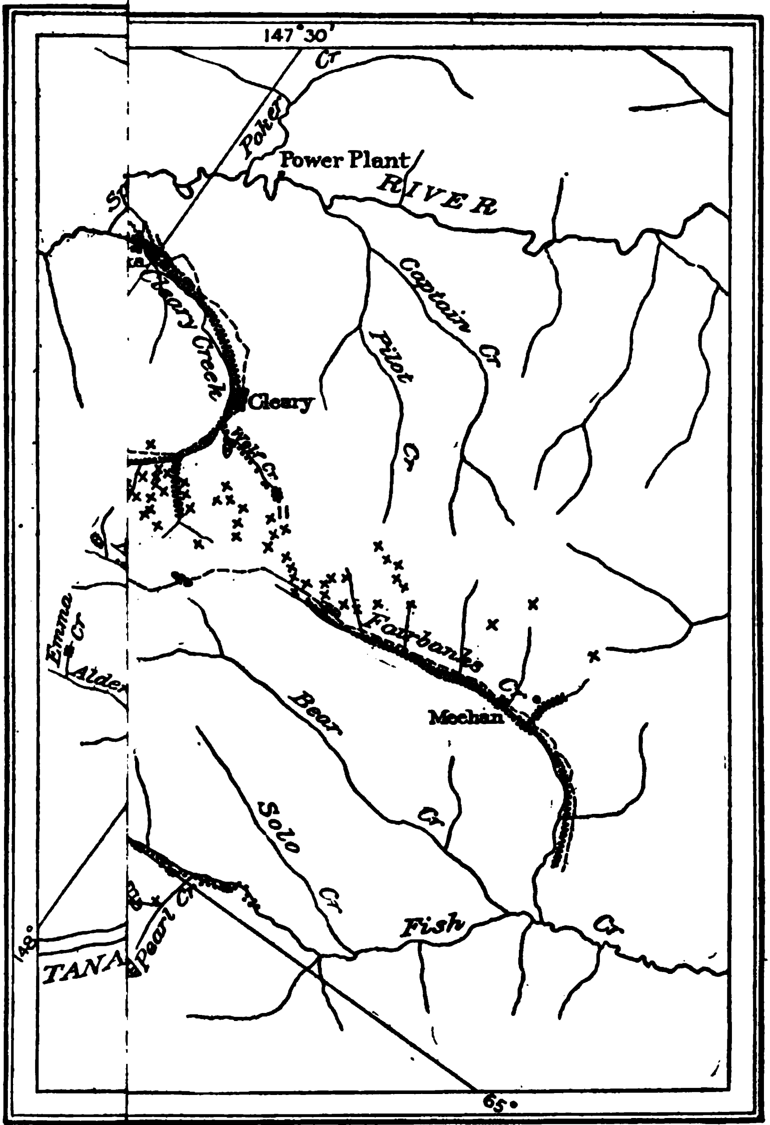
[1] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, 1916.

[2] Chapin, Theodore, Lode mining near Fairbanks: U. S. Geol. Survey Bull. 592, pp. 327-328, 1914.



By L. M. Prindle, F. J. Katz, P. S. Smith,
Theodore Chapin, A. H. Brooks, and J. B. Mertie, Jr.

was encountered, and both branches of the vein have been followed for some distance. The leaner of these, about 10 to 12 inches thick, has a general strike of about N. 80° W. and a steep dip to the north. It was followed for about 150 feet to a point at which the vein strikes about N. 50° W. The other branch of the vein, which strikes N. 75° W. and dips steeply south, is considerably richer, though thinner, ranging from 4 to 6 inches in thickness. This higher-grade gold quartz vein at the time of the writer's visit had been followed 125 feet from the forks and is traceable at the surface northwestward for 2,000 feet from the mouth of the tunnel, extending into the Nars claim. Stibnite, arsenopyrite, and a little sphalerite occur with this gold quartz.

At the upper end of the Hiyu claim a vein of low-grade gold quartz about 2½ feet thick has been uncovered. This strikes about east and dips about 80° N. and should intersect the two veins above described. Kidneys of stibnite are present in the quartz.

MIZPAH.

The Mizpah mine was operated for several months in 1916, during which about 200 tons of ore was mined and milled. In the fall of 1916 the owner was preparing to continue mining operations on the property.

The Mizpah lode is a gold quartz vein which strikes from east to S. 70° E. and dips about 65° SW. It has been opened by an inclined shaft 120 feet deep and by tunnels driven east and west from the shaft. No drifting has yet been done at the bottom of the shaft, but the owner expects soon to sink the shaft 60 feet deeper and begin another tunnel. At the 80-foot level a tunnel has been driven 130 feet west along the vein and another has been driven 60 feet to the east. At 40 feet above and parallel with the west tunnel a stope has been driven 110 feet from the shaft.

The gold quartz vein is irregular, ranging in thickness from 3 inches to 3 feet, with an average thickness for the mine of about 1 foot. Horses are present at several places. Irregular veins of white vitreous quartz (bull quartz) also occur in the mine workings; but these are entirely barren of gold, except where they adjoin the true gold quartz veins and have been locally mineralized. In this mine the gold quartz vein may be seen definitely cutting the bull quartz, and this, in conjunction with the local mineralization of the bull quartz, is ample evidence that the gold quartz vein is the later.

About 1 foot of gold quartz is present at the face in the west tunnel, of which the 4 inches on the hanging wall is the richer in gold. At the west end of the stope, above the west tunnel, the face shows a vein split by a horse, the north side being about 12 inches and the south side about 6 inches thick. That part of the vein south of the horse, or on the hanging wall, is of higher grade than the remainder of the vein. At the end of the east tunnel much faulting has taken place, and the gold quartz is replaced by earthy wad and oxidized silver-lead ore.

The gold is confined almost entirely to the quartz, but a little is present in gouge here and there along the walls. Stibnite occurs in some parts of the vein, and such parts assay abnormally high in gold, indicating gold enrichment by the antimony ore. Thus in the west tunnel, about 80 feet from the shaft, some stibnite is present in the gold quartz, and some ore yielding as much as $2,000 to the ton is reported to have been mined. The average yield of the gold so far mined is between $30 and $40 a ton.

HOMESTAKE.

The Homestake mine was operated in 1916 by three lessees, and 80 tons of high-grade ore was mined. The most important recent development at this mine was the discovery by the laymen of another productive ore shoot in the vein from which the gold ore is now being taken.

The Homestake mine was visited by Chapin [1] in 1913, and the lode system was described by him in considerable detail. At that time the main tunnel had been driven south about 750 feet, and a drift had been turned off to the east on the main gold quartz vein at a distance of about 320 feet from the tunnel entry. The gold appeared to be present in shoots which were separated by barren vein material. The drift intersected such an ore shoot, which had an east-west extent of about 160 feet. About 135 feet from the mouth of the drift, within this ore shoot, a raise to the surface demonstrated that the shoot ended not far above the drift, but a similar shoot was encountered 30 feet up the raise from the lower one. The operations during 1913 consisted largely in stoping and mining out these two ore shoots.

The present lessees have driven another raise near the east end of the main drift and have discovered a new ore shoot in the vein about 100 feet above the drift, from which ore is now being mined. To facilitate mining operations a new tunnel has been started up the hill and east from the old tunnel. This tunnel, however, if continued, would strike the vein below the new ore shoot, and therefore near the face a short inclined raise was driven east to the ore body.

Chapin [2] described a horizontal fault in the main drift along which a general east-west movement had taken place parallel to the strike of the vein without displacing the vein. The owners of the mine in following east in the drift have determined that this horizontal fault becomes curved. At the point where the new raise was driven the strike of this fault is N. 60° E. and the dip 30° NW. Other movements, however, have taken place in this vicinity, as shown by the presence at the east end of the drift of a fault striking N. 40° E. and dipping 58° NW., and the composite effect of the faulting is not altogether clear. The strike of the gold quartz vein at the new ore shoot is N. 68° E. and the dip 40° SW. This observation, in conjunction with those of Chapin, indicates considerable variation in the strike of the vein—perhaps as much as 25°

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[1] Chapin, Theodore, Lode mining near Fairbanks: U. S. Geol. Survey Bull. 592, pp. 331-334, 1914.

[2] Idem, p. 333.

The country rock ranges from a mica schist to a quartzite schist and locally shows a jointing striking N. 65° W. and dipping 75° SW. The gold, however, is confined entirely to the quartz vein. Some stibnite is present in the mine, and pyrite and chalcocite were also seen in very small amounts. Much white vitreous quartz (bull quartz) occurs in the mine, but, as in the Mizpah mine, this is barren except where enriched by contact with the gold quartz vein.

MOHAWK.

The Mohawk lode is situated at the head of Eldorado Creek, at an elevation of about 2,150 feet, due south of the Newsboy mine. The mine was operated by two men for four months in 1916 but was closed at the time of the writer's visit on account of litigation. During the four months 46 tons of ore was mined and milled.

A working shaft about 50 feet deep has been sunk, from which two short tunnels have been driven west and east. The west tunnel, 25 feet long, intersects at its west end a vein of gold quartz, from 16 to 18 inches thick, which strikes N. 20° E. and dips 60° W. At the end of the east tunnel there is another vein, with the same strike and dip, ranging in thickness from 30 to 42 inches. These appear to be parallel veins, though it is possible that they may be faulted portions of the same vein. Both veins have been followed only a short distance. The gold is largely free. Stibnite, pyrite, and arsenopyrite in small amounts are also found in the vein. One of the owners, T. E. Winecoff, reports the presence of some osmiridium in the ore.

About 75 feet northwest of the working shaft another shaft, said to be 30 feet deep, has been sunk. This was filled with water and inaccessible, but it is reported to have uncovered another quartz vein, striking N. 80° W. and dipping 35° SW. The material on the dump at this shaft showed considerable arsenopyrite in the quartz.

NARS, ANDERSON & GIBBS.

No work was in progress at the property of Nars, Anderson & Gibbs in August, 1916, but it is reported by one of the owners that 100 tons of ore was mined sometime in 1916. The earlier work at this property and the character of the mineralization have been described in some detail by Smith.[1] The working shaft was inaccessible at the time of the writer's visit, and no further information concerning the development work is available at present.

OHIO GROUP.

The Ohio group of claims, consisting of the Ohio, Mayflower, Early Bird, and Gray Eagle, lie along the north slope of Fairbanks Creek west of Too Much Gold Creek and east of the Mizpah lode. Mining at present is being done on a small scale, the work being more in the nature of prospecting than of mining.

A number of shafts have been sunk on the Ohio claim, exposing several gold quartz veins. Most of these shafts were examined by the writer, but it is difficult to correlate the different veins without a map showing the location of the shafts. Moreover, observations made in the shallow shafts are not trustworthy on account of surface creep, and at this locality the presence of an old creek channel along the hillside has induced creep in the bedrock at depth, rendering some of the information obtained in the deeper shafts likewise untrustworthy. However, it is apparent that a number of quartz veins are present, and the owners, recognizing the difficulty and uncertainty of prospecting along the hillside, have adopted the only alternative and are driving a tunnel from a lower elevation on the hill to crosscut the vein systems. This tunnel, which is to be 800 feet long, runs N. 30° W., and in August, 1916, had been driven 240 feet. Not only will this tunnel be a means of prospecting all the veins, but it will also afford an easy outlet for the ore to the mill on the property.

Several shafts on the Ohio claim were examined. One of these, 25 feet deep, showed two quartz stringers, close together and coalescing in places, with a general strike of N. 70° W. and a dip of 45° SW. This quartz is commercial ore.

Another shaft, 57 feet deep, has exposed 8 inches of low-grade gold quartz, averaging perhaps $4 to $5 to the ton. This vein strikes east and dips about 45° N.

From the bottom of a third shaft, 70 feet deep, a drift 70 feet long has been driven, starting east and then turning north. In this drift is exposed a gold quartz vein, 4 to 6 inches thick, which strikes east and dips 45° NW. A shattered and iron-stained ledge of the bull quartz is also exposed, but this appears to be barren of gold. It is clear here, as at the Mizpah and Homestake mines, that the auriferous quartz is later than the barren bull quartz. The gold quartz exposed in this shaft is good commercial ore. It contains also pyrite and stibnite.

Higher up the slope, on the Ohio claim, a 30-foot shaft has exposed a body of "base" ore, the exact extent of which is not known. A piece of rock from the bottom of the shaft appears to be a recrystallized rock of a green color and impregnated with quartz, pyrite, and arsenopyrite. A globule of silver is reported to have been obtained from some of the oxidized ore, which resembles very much the silver-lead ore in the Mizpah lode.

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[1] Smith, P. S., Lode mining near Fairbanks: U. S. Geol. Survey Bull. 525, p. 155, 1913.

On the Early Bird claim 12 to 15 inches of stibnite in a kidney-shaped body was uncovered in a 25-foot shaft.

Gilmore & Stevens, owners of the Ohio group of claims, installed in 1915 a 5-stamp mill, in which 800 tons of ore has been milled. Of this amount 350 tons has been taken from the gold quartz veins on the Ohio group, most of which was milled in 1915. At present the owners are engaged chiefly in driving the tunnel above described.

CENTER STAR.

The Center Star claim, on Skoogy Gulch, a tributary of Twin Creek, was worked during 1916. The ore was milled on the ground by a home-made single-stamp mill, driven by a 6-horsepower gasoline engine.

A shaft about 45 feet deep has been sunk, at the 35-foot level of which drifts have been driven 25 feet to the west and 150 feet to the east. The gold occurs in a 3-inch stringer of quartz, which strikes N. 85° W. and dips steeply to the south. The country rock is a quartzite schist, barren of gold. The gold ore is of high grade.

ST. PAUL.

The St. Paul claim, near the head of Eva Creek, southeast of Ester Dome, was actively prospected during the spring and the early part of the summer of 1916, and late in the summer a 7-foot roller mill, with a capacity of 20 tons in 24 hours, was installed. This mill is equipped with an inside amalgamator and is run by a 30-horsepower boiler. During the remainder of the year 370 tons of ore was milled.

The workings consist of a 15-foot shaft, from the bottom of which a 15-foot inclined shaft was driven to prospect the ore, and a main tunnel, starting at a lower elevation than the shaft and driven 227 feet, meeting the bottom of the shaft.

The lode on the St. Paul claim is of considerable interest, because it illustrates a phase of the gold mineralization different from that seen at most of the lode mines in the Fairbanks district. The gold lode material is a 3-foot vein of the massive white vitreous quartz usually found to be barren of gold in the district. This vein is irregular in thickness, strikes generally about N. 40° E., and dips 38° NW. The quartz is greatly decayed, shattered, and iron stained, as is also the quartzite schist and mica schist country rock. There is said to be from 8 to 10 inches of ledge matter on the footwall, and about 6 inches of the same on the hanging wall. Irregular bodies of stibnite and its alteration products occur along the footwall, but the gold content is said to be lower near this stibnite. At the face of the tunnel, in August, 1916, a fault had been encountered, and the width of the ore body was reduced to a few inches.

It is perfectly clear that this is not true gold quartz, similar to that in most of the Fairbanks mines. The gold mineralization is clearly a feature of later age than the formation of this body of shattered quartz. The writer's interpretation of this lode is that it represents a deposition of gold from solution with little or no accompanying gold quartz. It is believed that the 3-foot vein of quartz in the St. Paul lode bears no genetic relation to the gold, being probably an old barren quartz vein, similar to hundreds of other such bull quartz veins in the Birch Creek schist. The localization of the gold in this quartz was more likely due to a mechanical cause, as the quartz on account of its brittleness was extensively broken and shattered in earth movements prior to the injection of the mineralizing solutions, to which it therefore offered channels of easy circulation. It is also possible that the quartz, on account of its siliceous nature, may have influenced the deposition of the gold. The fact to be emphasized, however, is that this material does not resemble the ordinary Fairbanks vein quartz, either in appearance or in manner of occurrence. The writer was rather impressed by the resemblance of this lode system to the normal type of gold lodes in the Nome district; but the St. Paul lode differs from the gold lodes on Seward Peninsula in that the gold here is largely free.

The deduction to be made from these considerations is that the quartz in the St. Paul lode is likely to be irregular, in a degree corresponding to the irregularity of the old series of barren quartz veins. The quartz is indeed likely to be discontinuous or to disappear entirely, though the lode may continue as a fault zone in the schist, with or without true gold quartz. The absence of vein quartz is not in itself to be considered detrimental to the future of the lode. The mistake to be avoided is that of following blindly the quartz as a source of gold, for the deposition of the gold in a body of quartz was in all probability fortuitous and not to be ascribed to generic association. The direction of the zone of faulting, indicated by the maximum of shattering and iron staining, should determine the continuation of the lode.

INDEPENDENCE.

The three claims that constitute the Independence group are staked end to end in an east-west direction on the east slope of Twin Creek, just below the mouth of Skoogy Gulch. Independence claim No. 1 crosses Twin Creek and extends some distance up the west slope. The lode was discovered in 1915, and the development work was done for the most part last winter. Mill runs on the ore have been made in an arrastre built on Twin Creek.

The Independence lode is a mineralized zone in porphyritic granite, extending in a general easterly direction. Two small tunnels have been driven on the east slope of Twin Creek on Independence claim No. 1, in the upper of which 18 inches of vein quartz is exposed. This vein strikes east and dips 90°. Many iron-stained joint planes carrying gold are present in the surrounding country rock. Some of these lie at right angles to the strike of the veins, but others are irregular. Many small quartz veinlets, likewise irregularly placed, also carry gold. The quartz veins and stringers in this lode are high-grade ore, and the rock on the dump may be considered as workable commercial ore. The granite on both sides of the zone of intensive mineralization gives low assays in gold, but it is not known yet how far on each side rock of this sort extends. The mineralized zone has been traced at the surface for 900 feet east from the tunnels.

Considerable pyrite and arsenopyrite occur with the gold quartz, and both these minerals carry gold, probably for the most part in a finely divided condition. About one-third of the gold is said to be recoverable when the ore is crushed to 40 mesh, the remaining two-thirds being contained in the sulphides.

GOESSMANN.

The Goessmann claims have been described in some detail by Smith.[1] under the head of the Tanana Quartz & Hydraulic Mining Co.'s claims. They consist of nine claims on the east side of Bedrock Creek, just above its junction with Cleary Creek. No work was in progress at the time of the writer's visit, and no further description of the property will be given here.

McCARTHY.

The McCarthy claims are in the saddle that separates Fairbanks and Wolf creeks on the Fairbanks slope. Nine claims constitute the group.

The latest work done on these claims is on the Pioneer claim near its center, where two shafts have been sunk on an antimony lead. The vein varies considerably in thickness, averaging perhaps 18 inches. The strike is N. 85° E. and the dip is about 80° N.

About 500 feet to the west, on the Pioneer claim, three gold quartz veins have been uncovered. One of these is 12 inches in thickness, strikes N. 45° E., and dips 60° NW.; another, 35 feet farther west, is 14 inches thick, strikes N. 35° E., and dips 80° NW.; the third, still farther west, is 6 inches thick, strikes east, and dips 45° S. It is reported that these three veins will average $10 to the ton.

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[1] Smith, P. S., Lode mining near Fairbanks: U. S. Geol. Survey Bull. 525, pp. 180-182, 1913.

On the Iron Mask claim and continuing west into the Pioneer, a vein of stibnite 8 inches thick has been discovered, which strikes N. 80° W. and dips about 75° S. Near by, also on the Iron Mask, there is a large vein of low-grade gold quartz, striking N. 42° W. and dipping 70° N. This vein, which is about 4 feet thick, is reported to intersect and therefore to be younger than the stibnite vein above described. This large vein of low grade gold quartz also carries stibnite, and both this and the other stibnite on the Iron Mask pan gold. The large quartz vein has been traced southeastward to Fairbanks Creek, and the ore in that direction is said to become of higher grade.

MONTE CRISTO AND GRANITE HILL.

The Monte Cristo claim is on the spur between Melba and Monte Cristo creeks. The development work to date consists of a shaft 18 feet deep, now caved.

This is an interesting lode because of its obvious genetic connection with a body of porphyritic biotite granite, which forms the country rock at this locality. According to a description given by the owner two quartz veins separated by about 3 feet of shattered granite were exposed in the shaft. The strike of these veins is said to be N. 5° W. and the dip 80° W. The east vein has a thickness of 3 to 4 inches and was uniform to the bottom of the shaft; but the west vein, though 18 inches thick at the surface, pinched out a few feet from the bottom.

The quartz contains gold, scheelite, bismuthinite, and according to assay some mineral containing tellurium. A feature worthy of particular mention at this shaft is the apparent independence of gold and tungsten in the lode. The gold is associated with the bismuth and tellurium, being in fact intergrown with the bismuth minerals. The scheelite, on the other hand, is said to occur in portions of the vein where gold is absent. This condition is exactly in accord with that found in the scheelite lode on the Black Joe and Mizpah claims.

On the Granite Hill claim, adjoining the Monte Cristo, is another bismuth-bearing gold quartz vein, which has previously been described by Chapin.[1] No recent work has been done on this claim.

SMITH & McGLONE.

A number of gold quartz claims on the ridge between Eva and St. Patrick creeks are owned by Smith & McGlone and are being intensively prospected. Shafts have been sunk on several gold quartz veins, some of which, now inaccessible, have been described by Chapin.[2] The owners have by this time a fairly good idea of the mineralization of their claims, and when the inevitable revival of lode mining begins in the Fairbanks district, they should be in a good position to begin active work.

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[1] Chapin, Theodore, Lode mining near Fairbanks: U. S. Geol. Survey Bull. 592, pp. 330-331, 1914.

[2] Idem, pp. 354-355.

The present work is being done on the Leah fraction. A 95-foot shaft has been sunk, showing a vein of gold quartz from 2 to 3 feet thick, lying in and parallel with a mineralized zone from 3 to 11 feet wide. The strike of the vein is N. 45° E. and the dip 55° SE. Both the gold quartz and the white vitreous bull quartz were seen in the mineralized zone, but here, as at the St. Paul claim, the bull quartz is mineralized. A specimen taken by the writer shows some of this vitreous quartz, much broken and shattered, filled with stibnite, proving the later character of the mineralization. A little sphalerite is also present in this lode. That portion of the lode which adjoins the quartz vein proper is much shattered and filled with quartz stringers. This part of the lode, though not as high-grade ore as the main quartz vein, also carries gold and may probably be worked. The gold quartz proper is good commercial gold ore. It is reported to the writer that the gold content is higher where stibnite is present in the lode.

RYAN.

Prospecting continued in 1916 on the Ryan group of eight claims at the head of St. Patrick Creek. The present workings consist of a shaft 28 feet deep, sunk on the side line between the Monte and Eva claims, which has exposed a large body of quartz.

The lode consists of a shattered mixture of quartz and country rock, lying in a zone which strikes N. 25° E. About 15 to 20 feet of ore was exposed at the time of the writer's visit. This is evidently another mineralized zone, comparable in character with that seen at the St. Paul claim. The mineralization has seemingly occurred along a zone of fracture and is not confined to a gold quartz vein. Much arsenopyrite is present in the lode, and the green alteration product scorodite extensively colors the lode material.

On the Ryan claim a shaft has been sunk 35 feet, at the bottom of which there are kidneys of quartz lying in a mineralized zone of schist. As at the other shaft, much arsenopyrite is present. It is said that the gold content is higher where there is the least arsenopyrite, but the suggestion is advanced that the arsenopyrite itself may contain gold that is not free. Kidneys of stibnite also are present in the gouge.

TYNDALL & FLYNN.

The Bondholder group of claims, owned by Tyndall & Flynn, is near the head of Gold Gulch, a tributary of St. Patrick Creek. The mineralization on the Bondholder claim has been described by Chapin,[1] who says that a lode which strikes N. 20° E. and dips 40° NW. has been traced for 500 feet on the surface and across the length of three adjoining claims to the northeast. This lode is 6 feet wide and is composed of quartz with inclusions of schist. The hanging wall is bounded by gouge, and along this side of the vein the richest ore occurs in a green-stained quartz stringer. The footwall is not well defined, being made up of a number of parallel joint planes, each with a narrow seam of gouge.

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[1] Chapin, Theodore, op. cit., p. 355.

The lode on the Bondholder claim has been prospected by three shafts, one 140 feet deep, another 145 feet deep, and a third shallow shaft. All these are now in poor condition. Ore from this lode, seen by the writer, resembled to a marked degree the ore on the Ryan lode, containing arsenopyrite and the green alteration product scorodite. This is reported to be high-grade commercial ore.

A tunnel has been started on the Yellowjacket claim, east of the Bondholder, and is being driven to crosscut the Bondholder lode. Between 600 and 700 feet of tunnel has been driven, but the lode had not yet been reached in August, 1916. This tunnel shows many well-developed joint planes in the schist country rock, which strike N. 20° W. and dip 85° E. Near the face many horizontal or nearly horizontal faults occur, and one small seam of quartz and calcite, carrying some pyrite, was noted.

On the Mohawk claim, also owned by Tyndall & Flynn, two shafts 40 feet deep have been sunk, exposing an 8-foot vein of quartz, with little or no gouge. Stibnite and a little sphalerite are contained in the quartz. It is probable that this is a continuation of the lode now being prospected on the Leah fraction by Smith & McGlone.

OTHER MINES AND PROSPECTS.

There are a large number of other gold quartz mines and prospects in the Fairbanks district; but on account of present conditions a number of gold quartz mines are not being operated, and prospecting is not being prosecuted very actively. The omission of reference to gold quartz mines and prospects, which have been described in earlier reports is to be considered only as an evidence of lack of mining activity and not as an indication of lack of intrinsic worth.

SULPHIDE ORES.

A variety of metallic sulphides have been discovered in the Fairbanks district, including stibnite, galena (in part silver-bearing), pyrite, arsenopyrite, sphalerite, bismuthinite, jamesonite, chalcocite, and tetrahedrite. Of these only stibnite and galena have been found in lodes of commercial importance.

A number of antimony mines were operated in 1916; but all of them except the Chatham mine were closed in August. Stibnite is known to have been mined at the Chatham mine, the Black Eagle mine, the Hindenburg claim, and at the Leindecker property.

One silver-lead lode, near the head of Cleary Creek, was worked by the Eldorado Mining & Milling Co.

CHATHAM.

The Chatham mine, near the head of Chatham Creek, is in reality a gold mine; but during the season of 1916 it was worked for the antimony ore which it contained and hence the 2-stamp mill on the property was idle.

The main tunnel has been driven 1,300 feet; but the present work in the mine is being done largely in a stope above the tunnel, about 850 feet from the entry. A raise has been driven 100 feet to the surface, and 60 feet above the tunnel in this raise is the stope from which the antimony ore is being removed. The vein, which is about 18 inches thick, is almost vertical and strikes N. 70° E. Several feet of gouge lies along the footwall, usually the south side of this vein, but the hanging wall is firmer. The ore is stibnite. This vein is said to cut the main gold quartz vein of the Chatham mine at an angle of 85°.

About 20 feet from the raise a shaft has been sunk 32 feet from the floor of the tunnel, striking the stibnite vein below. Mining is also being carried on at the bottom of this shaft, but pumping is necessary.

HINDENBURG.

The Hindenburg claim, at an elevation of about 1,600 feet on the divide between Spruce and Eldorado creeks, was worked for stibnite during the summer of 1916 by Poz & Contardi, but the mine was idle at the time of the writer's visit in August. Seven or eight men were employed during the early part of the summer. It is reported that 200 tons of ore was shipped from this property.

The workings consist of a shaft 25 feet deep, with drifts from the bottom. The ore body is said to lie nearly flat, dipping about 60° SE.

BLACK EAGLE.

The Black Eagle mine, on Eagle Creek, a southwesterly tributary of Treasure Creek, has been described in some detail by Brooks.[1] This property was closed and was not visited by the writer. It was the largest producer of stibnite in the district in 1916.

LEINDECKER.

On the Leindecker property, at the head of Too Much Gold Creek, no operations were in progress in August, 1916.

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[1] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, pp. 28-29, 1916.

ELDORADO MINING & MILLING CO.

The Eldorado Mining & Milling Co. is working a lode on two claims on the southeast side of Cleary Creek, just above the mouth of Willow Creek. This is the only silver-lead lode in the district that is being worked at the present time.

An open cut and a 40-foot shaft are the principal workings. The country rock is a fine-grained quartzite, and the vein as exposed in the open cut ranges in thickness from 3 to 12 inches and lies parallel with the structure of the country rock. The ore at present being mined is argentiferous galena with considerable pyrite. The value of the ore taken from the shaft, as given to the writer by one of the lessees, classes this as a good commercial ore of silver and lead. The ore also carries a little gold.

JACKSON.

The Jackson claims consist of the Little Jim, Big Jim, Our Jim, and Your Jim, near the top of the spur between Bedrock and Tamarack creeks; and the Vergil and Wolverine, near the top of the spur between Willow and Bedrock creeks. The Jim claims are here described under the head of sulphide lodes, though they also contain gold. Prospecting has been carried on intermittently on these claims for several years.

The lodes on the Jim claims contain a variety of minerals, including stibnite, silver-bearing galena, pyrite, arsenopyrite, and gold both in the free state and combined with the sulphides. Chapin[1] has described the character of the lodes, and the writer in this report will sketch only the developments in prospecting, reserving for a later paper the description of certain interesting features of the ores on this property.

The Little Jim claim is the same as that described by Chapin as the Silver King. An open cut 50 feet long on this claim has exposed a 2-inch vein of sulphide ore, largely galena with some stibnite, which strikes east and dips about 25° S. The country rock is mica schist and both walls lie parallel to its schistosity. Both the vein and the country rock are cut by a fault that strikes N. 75° W. and dips 90°. About 25 feet south of the open cut a shaft is being sunk to intersect the lode. This ore also contains pyrite and is reported to carry considerable silver.

Another open cut on the Little Jim claim, about 250 feet northeast of the cut just described, has exposed a flat-lying seam of sulphide ore, which contains well-formed crystals of quartz intergrown with the sulphide. This vein where observed by the writer is about 4 inches thick, strikes N. 45° E., and dips at a low angle to the southeast. The ore is described by Chapin[1] as being essentially a sulphantimonate of lead, probably jamesonite, but it contains also galena, arsenopyrite, pyrite, and possibly stibnite. Both walls lie parallel with the schistosity of the country rock, which for 6 or 7 inches on each side of the vein is heavily iron stained and carries from $6 to $7 a ton in gold. The sulphide ore carries considerable silver.

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[1] Chapin, Theodore, Lode mining near Fairbanks: U. S. Geol. Survey Bull. 592, pp. 338-339, 1914.

A shaft has been sunk to a depth of 60 feet on the corner between the Little Jim, Your Jim, and Our Jim claims. A drift started about 25 feet south of that point has exposed a vein of sulphide ore, composed of galena and arsenopyrite with a little pyrite, which strikes N. 45° E. and dips about 45° SE. This vein cuts the cleavage of the country rock. A short distance away, on the Big Jim claim, a flat-lying antimony vein was encountered. The shaft and drift by which this was prospected are now caved.

A tunnel 516 feet long has been driven, starting on the Big Jim claim, following the line between the Our Jim and Your Jim claims, and ending at the northwest corner of the Little Jim claim. A number of faults are apparent in this tunnel, most of which have a strike somewhat north of west. At 70 feet from the entry a fault striking N. 45° E. and dipping 65° NE. cuts across the tunnel. At 123 feet from the entry is another fault, striking N. 75° W. and dipping 75° S. At 200 feet is a third fault, which strikes N. 75° W. and dips 65° S. At 300 feet is exposed a fourth fault plane, likewise striking N. 75° W. and dipping steeply south, along which there is about 4 inches of crushed vein material and gouge that contains sulphides carrying gold. Several faults occur 380 feet from the mouth of the tunnel, and along one of them, striking N. 40° W. and dipping 45° N., is 18 inches of soft gouge, which is reported to yield a small amount of silver. Much faulting has occurreed at the rear of the tunnel, and some of the faults are curved. The country rock is quartzite, quartzite schist, and mica schist. The area included in these Jim claims has evidently been a center of dynamic disturbances and mineralization.

A shaft 14 feet deep with a drift extending 4 feet south from the bottom has been sunk on the line between the Vergil and Wolverine claims. The ore consists of iron-stained country rock impregnated with quartz and antimony ore, in a mineralized zone about 8 inches wide, striking N. 55° E. and dipping 15° SE. The hanging wall is quartzite schist and the footwall mica schist. A fault striking N. 80° W. and dipping 70° S. is present in the bottom of the shaft, but this appears to be earlier than the mineral injection, for it does not displace the ore.

The ore is stibnite with several oxidation products and is reported to carry both gold and silver.

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[1] Chapin, Theodore, op. cit., pp. 338-339.

TUNGSTEN LODES.

GENERAL FEATURES.

The Geological Survey has known for a number of years that tungsten lodes were present in the Fairbanks district, for tungsten minerals have been found in the gold placers on several creeks. Thus in 1909 Johnson,[1] in summarizing the known occurrences of tungsten minerals in Alaska, referred to the discovery by L. M. Prindle of wolframite on Fairbanks and Little Eldorado creeks. The concentrates from Fairbanks and Fish creeks are known to carry scheelite, and it is probable that close examination may show tungsten minerals in numerous other creeks.

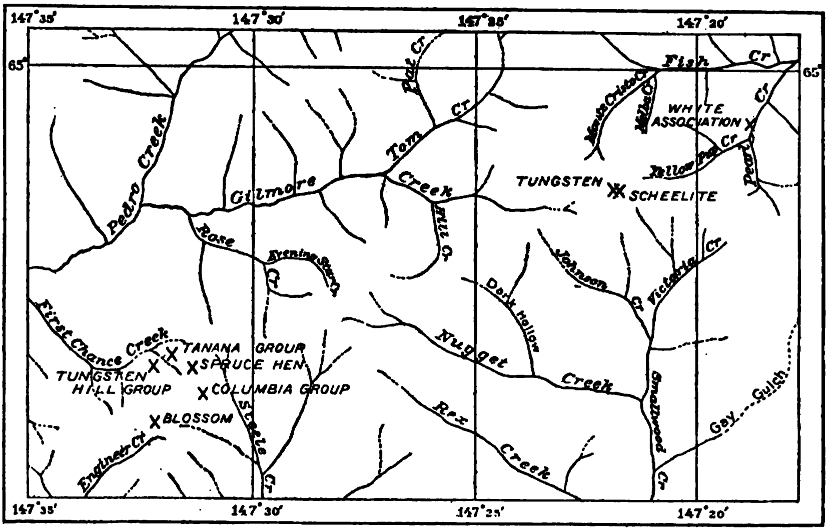

FIGURE 8.—Sketch map showing tungsten lode claims in the Fairbanks district.

During the summer of 1915 the bedrock source of some of these tungsten minerals was discovered, and tungsten lodes became another of the mineral resources of the Fairbanks district. Prospecting has centered chiefly at two localities, one on the ridge between Fish and Smallwood creeks and the other on the ridge at the heads of First Chance, Steele, and Engineer creeks. Two workable scheelite lodes have been opened at the former locality, and a number of promising occurrences of scheelite are being prospected at the latter. In addition, a small lode on Fairbanks Creek was worked.

The following description of the scheelite lodes is intended mainly as a report of progress. A later report, dealing with the tungsten deposits of Alaska, will give more detailed information regarding the lode systems and their genesis. Figure 8 shows the distribution of the tungsten lodes in the Fairbanks district.

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[1] Johnson, B. L., Occurrence of wolframite and cassiterite in the gold placers of Deadwood Creek, Birch Creek district, Alaska: U. S. Geol. Survey Bull. 442, p. 246, 1910.

TUNGSTEN.

The Tungsten claim, owned by George Ewers, is on the divide between Fish and Smallwood creeks, on a prominent dome at the heads of Melba and Monte Cristo creeks. Scheelite was discovered on this claim in the summer of 1915, and mining was begun in the fall of that year and continued into the summer of 1916. In August, 1916, an 18-horsepower gasoline engine and an air compressor had been ordered, and the owner was preparing to put in a track, install a skip, and begin operations on a larger scale.

The development work up to August consisted of an 80-foot incline, at an angle of about 33°; a 35-foot drift to the east about 50 feet down the incline; and another drift some distance to the east at the bottom of the incline. It was from this lower drift that the latest shipment of ore was mined.

The country rock at the Tungsten, as well as at the adjoining Scheelite claim, consists largely of crystalline limestone, extensively silicated at certain horizons. Such silicated rocks have been described by Prindle[1] under the designation "silicated limestone." His conclusion regarding the origin of these rocks is as follows: "The most probable tentative explanation is that these rocks were impure calcareous sedimentary rocks containing basic or interbedded tuffaceous material, and that they were metamorphosed while they were deeply buried."

The silicated portions of the country rock at the Tungsten and Scheelite claims contain calcite, pyroxene, hornblende, and quartz. Thus there are pyroxene-quartz, hornblende-quartz, and pyroxene-calcite rocks, as well as rocks of intermediate type. One specimen of a pyroxene-calcite rock shows the two minerals in poikilitic intergrowth. Hornblende schist and mica schist also occur in the near vicinity. It is believed that the recrystallization of the country rock to its present condition was quite independent of any effect of the ore-bearing solutions—that is, the alteration of the country rock appears to be due to regional and not contact metamorphism.

The scheelite occurs as disseminated deposits in mineralized zones or as ore shoots in the country rock. In the drift that starts 50 feet from the surface several tons of ore was removed from a small ore shoot about 12 inches high and 18 inches across. The strike of this shoot was about N. 60° E., and the dip 25° NW. At the bottom of the shaft, another ore shoot, nearly horizontal, was opened. This body of ore 10 feet from the shaft is 7 feet wide and 8 feet high, but at the east end of the drift in August it is 4 feet wide and 6 feet high, apparently trending about east. The cleavage of the country rock dips 33° N., the same direction and pitch as that of the shaft. The first shipment of ore from the mine was taken from the inclined shaft, and it appears therefore that the ore-bearing solutions in that locality followed the rock cleavage. Ore deposition in general has probably been guided by the facility of circulation afforded by the country rock.

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[1] Prindle, L. M., Geology of the Fairbanks district, Alaska: U. S. Geol. Survey Bull. 525, pp. 62-64, 1913.

The rock that contains the scheelite is of particular interest, on account of the bearing which its character has on the genesis of the deposit. One specimen of ore examined under the microscope is composed of quartz, augite, scheelite, apatite, and chloritized biotite. A small amount of uralitic hornblende also is present, derived probably from the altered pyroxene. The scheelite occurs as euhedral crystals and appears to be secondary with respect to other rock minerals.

Another specimen, taken from the shaft by Mr. Johnson, a former part owner of the Tungsten claim, is apparently a tungsten-bearing pegmatite. The rock-forming minerals are quartz, oligoclase, scheelite, apatite, titanite, and a little biotite and hornblende, both chloritized. A small amount of sericite, apparently derived from the feldspar, is also present. The scheelite has developed as euhedral crystals, which contain anhedral inclusions of quartz and oligoclase, together with euhedral inclusions of apatite. The exact spot in the shaft from which the specimen was taken was not discovered by the writer, but it was assuredly an integral part of the deposit.

The Tungsten and Scheelite claims are about a third of a mile from a large body of porphyritic granite to the south and about two-thirds of a mile from a smaller body of similar intrusive rock to the north. Without much doubt these two bodies of granite ore are connected beneath the surface and therefore underlie this deposit of scheelite at no great depth. These data, taken in connection with the presence of the scheelite-bearing pegmatite above described, show the intimate genetic connection between the intrusive rock and the tungsten ore. This deposit of scheelite, then, particularly near the surface, where it is at present being worked, is a disseminated deposit, the tungsten-bearing solutions having been derived from a near-by granite magma. Mining operations closer to the igneous rocks may show the presence of definite contact-metamorphic deposits.

Fifty tons of scheelite ore was mined and shipped in the form of scheelite concentrates from the Tungsten claim in 1915, and 160 tons was mined, concentrated, and shipped in 1916. The ore was hauled to the Heilig custom mill on Fairbanks Creek for concentration and was afterward shipped by parcel post.

SCHEELITE.

The Scheelite claim lies immediately east of the Tungsten claim, and the mining and geologic conditions are identical at the two claims. The development work consists of a 75-foot inclined shaft along the cleavage of the country rock, which, though irregular, strikes in general about N. 70° E. and dips 33° N. The ore shoot which is followed by the inclined shaft, is 10 feet wide and from 4 to 6 feet high.

No mining was in progress at the time of the writer's visit, but 250 tons of unconcentrated scheelite ore was shipped to Tacoma, Wash., from the property during the winter of 1915–16. In August, 1916, the owner was preparing to sink a 100-foot vertical shaft and continue mining operations.

WHITE ASSOCIATION.

The White association consists of three placer claims on Pearl Creek, extending downstream from the mouth of the Yellow Pup. In addition to placer work, the owner has recently been prospecting at this locality for lode deposits of tungsten minerals.

Three shafts have been sunk, one to a depth of 30 feet, but these were not accessible when the property was visited. According to a description given by the owner, an ore shoot of scheelite has been located in the country rock, which is hornblende schist and mica schist. The strike of this body of ore is said to be N. 75° E. and the dip about 75° N. The schist has apparently been impregnated with scheelite along its schistosity. As might be expected, the concentrates from the placers on Pearl Creek contain scheelite.

BLACK JOE AND MIZPAH.

Scheelite was mined in 1916 by Ott & McGowon at the Black Joe and Mizpah claims, on Fairbanks Creek, adjoining the Mizpah mine. Work at this property had been discontinued at the time of the writer's visit. The development work consists of an inclined shaft, 90 feet deep, with drifts at the 60 and 80-foot levels.

The country rock is quartzite schist, which strikes N. 20° W. and dips 18° SW. The scheelite is present in a quartz vein, which cuts the cleavage of the schist, striking N. 80° W. and dipping about 80° S. This is really a gold-tungsten vein, for it contains both gold and scheelite. The interesting feature, however, is that the two minerals occur in different portions of the vein. Just above the 60-foot level the vein is 6 inches thick and is a gold-quartz vein, carrying little or no tungsten. Just below this level, in the same vein, the quartz is scheelite-bearing and the gold is lacking. In reality, there is a scheelite ore shoot in the quartz, with a lateral extent along the vein of about 80 feet. At the 80-foot level the vein is a low-grade gold-tungsten lode, carrying little gold and much less scheelite than at the 60-foot level. The dip of the vein at this point ranges from 45° to 85° S. It appears, therefore, that where this quartz vein carries scheelite in commercial amount gold is lacking, and that the gold-bearing part of the vein is lacking or low in scheelite.

TANANA GROUP.

The Tanana group consists of five lode claims along the northeast side of Tungsten Gulch, a headwater tributary of First Chance Creek. The claims are owned by Grant & Hirschberger, and during the summer of 1916 were being actively prospected for scheelite. Six scheelite lodes have been discovered on these five claims, and others are probably present.

The principal work has been done on the Tanana No. 1 claim. The country rock on this claim is a quartzite schist, the cleavage of which strikes N. 30° E. and dips 35° NW. The lode consists of a mineralized zone, 3 feet thick, which lies parallel with the major structure of the country rock. It is the structure of the schist, in fact, which has determined the site of the ore deposition. The scheelite occurs in stringers of soft, decomposed, iron-stained schist, from 2 to 6 inches in width. Many of these stringers contain little quartz-scheelite veinlets, which are very rich in tungsten and carry also some gold. The stringers of decomposed schist are said to carry both scheelite and gold. The country rock separating the schist stringers in the lode also carries a little scheelite, possibly as much as 1 per cent. A specimen of scheelite-bearing pegmatite, taken from the bottom of the incline, shows the intimate genetic connection of the deposit with granitic rocks.

A gold quartz vein striking N. 8° W. and dipping 60° E. cuts the schist and the scheelite lode above described. This vein carries gold in about the same amount as the scheelite lode. In view of the fact that gold and scheelite do not appear to have been deposited synchronously at the other properties visited, it is probable that the gold in this scheelite lode is a result of local enrichment by the gold quartz vein. Both structural and mineralogic data therefore point to the conclusion that the scheelite mineralization took place before the formation of the gold quartz veins, at least at this particular locality.

The Discovery lode on the Tanana No. 1 claim consists of 8 feet of scheelite-bearing schist, exposed in an open trench. The hanging wall at this place is porphyritic granite.

The Tanana group of claims, as well as the other claims in this vicinity, including the Spruce Hen group, the Columbia group, the Tungsten Hill group, and the Blossom claim, lie along the western periphery of a large intrusive mass of porphyritic granite. This is the same body of granite that lies north of the Tungsten and Scheelite claims, above described. The granite is intimately associated with the scheelite lodes, being present at the different claims as transverse dikes or wall rock, and in the Tanana No. 1 lode a scheelite bearing pegmatite occurs. It is quite evident, therefore, that the scheelite deposits at the west end of this intrusive mass are disseminated stringer lodes, much like the lodes at the Scheelite and Tungsten claims. Differences in the form of the deposits are due largely to the differences in the character of the country rock.

SPRUCE HEN GROUP.

The Spruce Hen group consists of three claims on the divide between First Chance and Steele creeks. These claims are being prospected by J. F. Zimmerman.

Five lodes are said to be present on the Spruce Hen claim. These are being prospected by open trenches. One trench has revealed a uniformly mineralized body of schist and metamorphosed basic intrusive rock, without any stringers or veinlets, from 3 to 4 feet wide, averaging perhaps from 1 to 2 per cent of scheelite. This lode carries no gold.

At another trench, on the same claim, is exposed a 4-foot lode of similar character which strikes N. 33° E. and dips 40° NW. This strike is conformable with that of the country rock on the Tanana No. 1 claim, and it is not improbable that this trend of the country rock has been determined to some extent by the intrusion of the neighboring granite mass, one tongue of which extends from the main mass in a northeasterly direction along the ridge.

COLUMBIA GROUP.

The Columbia group, comprising three claims, is at the head of Steele Creek, southeast of the Spruce Hen group. These claims are owned by J. Meier, J. Hoffmann, and W. Wallace. At the time of the writer's visit to this property, the development work consisted of a short tunnel at one locality and an open cut at another. Since that time, however, the tunnel has been driven 130 feet, and in midwinter the owners were installing a small mining plant.

The open cut is on the Columbia claim and has exposed a scheelite lode similar to the others previously described, cut by a 1-foot vein of quartz. Considerable wad is associated with the quartz, showing that the vein is to be classed with the gold quartz veins.

In the tunnel a 3-foot zone of scheelite-bearing rock was exposed. The hanging wall is a porphyritic granite, and the lode material consists of decayed stringers of country rock, rich in scheelite, similar to those at the Tanana No. 1 lode. The strike of the lode system is N. 20° W. and the dip 30° E.

TUNGSTEN HILL GROUP.

A group of eight claims, owned by Martin Harrais and known as the Tungsten Hill group, lies on the southwest side of Tungsten Gulch, a tributary to First Chance Creek.

Four scheelite lodes had been discovered on these claims by August, 1916, and it is likely that others are present. On the Grand Duke Nikolas claim a scheelite lode in the schist country rock had been exposed in an open cut. This deposit consists of 6 to 8 feet of decayed schist, carrying scheelite. Vein quartz containing a little gold is also present, cutting the mineralized zone.

On the Tungsten No. 1 claim another open cut had been made in a country rock of mica schist and quartzite schist. A zone mineralized by scheelite is present, but the width of the lode was not apparent from the work done.

On the General Joffre claim a scheelite lode, 14 feet wide, has been exposed. The lode as a whole was considered low-grade ore; but it contains in the central part an 18-inch stringer of decayed schist, which is of considerably higher grade.

These claims certainly deserve further prospecting, for they are as advantageously situated with regard to the granite as other scheelite claims in the district on which workable lodes have been developed.

ANDERSON CLAIM.

A lode claim adjoining the General Joffre claim, of the Tungsten Hill group, is owned by Charles Anderson. On this claim a quartz stringer striking N. 50° E. and dipping 55° NW. has been exposed in an open cut. The foliation of the country rock, which is largely a mica schist, strikes N. 60° E. and dips 20° NW. Scheelite is reported to be present along the outer edges of this quartz vein, but none is reported either inside the vein or in the adjoining country rock. It is likely that this quartz vein was formed first, and that at some later time the scheelite-bearing solutions percolated upward along the sides of the quartz and deposited scheelite in its present position.

BLOSSOM GROUP.

The Blossom group consists of several claims belonging to Victor Lundbled and Charles Anderson, at the extreme head of Engineer Creek.

A shaft on the Blossom claim is said to have exposed a rich stringer of scheelite, but this was not visible on account of timbering in the shaft. A granite porphyry dike is present in the bottom of the shaft.

At another claim of the Blossom group a shaft 20 feet deep has been sunk, opening a scheelite lode from 3 to 4 feet in thickness. This is another lode of the stringer type, but a thin quartz veinlet a short distance from the shaft was reported to carry 40 per cent of tungsten.

LODE MINING AND PROSPECTING ON SEWARD PENINSULA.

By J. B. MERTIE, Jr.

INTRODUCTION.

The lodes of Seward Peninsula give promise of coming importance but are as yet for the most part undeveloped. The Big Hurrah mine, in the Solomon district, produced gold from 1903 to 1907 but has not been operated since that time. Several small shipments of gold ore have been made from the Sliscovich mine, on Manila Creek, in the Nome district, but these were more in the nature of samples for mill tests than commercial shipments. Except on these two properties, gold lode development is still in the stage of prospecting.

Lode mining of some of the semiprecious and base metals, however, has been done on a small scale, though these lodes also are still largely undeveloped. Work has been done chiefly on tungsten, antimony, copper, tin, iron, zinc, silver-lead, and bismuth lodes. A beginning has also been made in the development of certain graphite lodes.

The following description of the Seward Peninsula lodes is intended to be merely a statement of progress and development work. A more complete account, describing in some detail the mineralization of the lodes and embodying the results of microscopic and metallographic studies, will be published later.

GOLD.

SLISCOVICH.

The Sliscovich mine, near the head of Manila Creek, has been described in some detail by Chapin,[1] and as little or no recent work has been accomplished, this description will not be elaborated. The latest shipment from this mine was made in the fall of 1915, when 88 tons of picked antimony ore was shipped to Tacoma, Wash. From data in possession of the writer it appears, however, that this ore contained considerable gold and a rather low percentage of antimony. This justifies the designation of the mine as an antimony-gold mine, rather than an antimony mine.

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[1] Chapin, Theodore, Mining on Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 592, pp. 403–404, 1914.

CALIFORNIA.

The California quartz lode is near the mouth of an east-side tributary of Goldbottom Creek, at an elevation of about 630 feet. This is the same property referred to by Chapin[1] as the Connelly & Jannsen quartz mine.

The lode matter consists of shattered quartz and country rock, which are heavily iron stained and mineralized. The ore body lies along a shear zone, which has a general strike of N. 15° W. The shearing seems to have taken place along a number of faults, with this general strike and with variable dips to the northeast, but to have been concentrated along the hanging-wall side of the shear zone. The hanging wall is therefore marked by a well-defined fault, with slickensided walls. Below the hanging wall, for about 4 feet, the lode matter is greatly crushed, iron stained, and mineralized, and it is from this part of the lode that the ore has so far been taken. The footwall is not well defined, the lode merging gradually into the country rock on that side.

The country rock in this vicinity is chlorite and sericite schist, with considerable graphitic slate and some thin bands of limestone. These rocks contain a system of old quartz veins, which are parallel to one another and lie conformably with the cleavage of the schist, striking N. 40° E. and dipping 50° SE. The shear zone, which strikes N. 15° W., cuts diagonally across the quartz veins and the character of the lode matter is therefore variable. At one locality it may be entirely the red, iron-stained, shattered schist; at another it may be dominantly the mineralized vein quartz. Thus on the north bank of the creek the shear zone intersects a 10-foot quartz vein, whereas on the south bank the mineralization is largely in schist.

The lode system is crosscut by the creek and well exposed. The mineralizing solutions were effective for a considerable distance laterally, for the iron staining is plainly apparent for 300 feet upstream from the lode and for a considerable distance downstream. The owner says that this zone of shearing may be traced 1 mile to the northwest and 2 miles to the southeast.

Pyrite and arsenopyrite are the principal mineralizing agents, but here and there a little free gold may be seen. In this as well as in most other gold lodes in the Nome district very little quartz has been introduced with the mineralizing solutions. Stibnite is reported to be present in seams 2 inches or less in thickness, but these were not seen by the writer. Hydrous manganese oxide is present in the gouge. Molybdenum and tungsten also are reported from assays.

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[1] Chapin, Theodore, op. cit., p. 402.

The development work to date consists of a 70-foot shaft, sunk on a 60° incline on the bank of the creek and an open cut near the shaft. The shaft was filled with water at the time of the writer's visit and such ore as was being mined was taken from the open cut. Mining was being done on a very small scale. A mill with three 1,000-pound stamps and a concentrator are utilized in treating the ore. The mill is run by water power, the water being delivered by a ditch from Fred Gulch. The mill has a rated capacity of 10 tons in 24 hours, but it is not at present in the best condition. The owner milled but 30 tons in 1915 and on account of the deep snow in the creek and mill trouble had milled only 8 tons by the last of September, 1916.

The 4 feet of ore along the hanging wall is said to have a value of about $50 a ton, as indicated by assays, but the owner has been able to obtain only from $8 to $10 a ton from the plates. It is therefore inferred that much of the gold is either mechanically intergrown with the sulphides, in particles of microscopic or submicroscopic size, or chemically combined with the sulphides.

STEINER.

The Steiner gold lode, owned by Martin Steiner, is on a spur between Penny River and one of its small tributaries, about 4½ miles from the mouth of Penny River, at an elevation of 200 feet. No work was in progress at the time of the writer's visit, and the shaft house was closed and the mine inaccessible. The shaft is reported to be 135 feet deep, and a tunnel at the bottom has been driven 100 feet to the east.

The rock on the dump is an iron-stained pyritized schist. Two kinds of quartz are present—one dull, opaque, and iron stained, and the other clear and granular. A little calcite is present in the clear variety. The relation existing between the two varieties of quartz is not known, nor are any data available concerning the character of the lode.

BOULDER CREEK.

A number of lode claims on Boulder Creek, owned by W. L. Cochrane and Claus Rodine, are being prospected for gold. The Boulder lode, embracing several of these claims, is on the southwest side of Boulder Creek, at an elevation of about 250 feet. Development work on this lode up to November, 1916, consisted of a tunnel driven 92 feet into the hillside, on the southwest side of the creek. The direction of the tunnel, S. 60° W., is about the same as that of the cleavage in the schistose country rock. The rock through which the tunnel is being driven is a much altered schist, heavily impregnated by iron-bearing solutions and cut by numerous veins and lenses of white, opaque quartz and also by thin stringers of limonitic material.

It is apparent that the gold in the tunnel has a genetic relation to the iron minerals, but it is not believed by the writer that the white opaque quartz had any direct connection with the gold mineralization, for the quartz shows the effects of shattering and iron impregnation in a measure comparable with the schist itself and therefore was present prior to the mineralization. The presence of the white opaque quartz is believed to be merely fortuitous, though it may have had an indirect influence on the mineralization by assisting mechanically or chemically in the precipitation from the mineralizing solutions.

The only quartz seen by the writer other than the white, opaque quartz was a veinlet of clear granular quartz, about three-eighths of an inch thick, near the face of the tunnel. Evidently the mineralization took place with very little deposition of silica by the auriferous solutions.

About 50 pounds of stibnite was taken from an open cut at the surface a short distance west of the tunnel. Scheelite in well-developed crystal outline has also been found in the white quartz in the tunnel. It is rather likely that the scheelite represents another stage in this mineralization, or possibly an entirely different period of mineralization.

At the time of the writer's visit to this lode the tunnel had been driven 85 feet, and although there was much evidence of mineralization in the iron-stained schist, sulphides in any notable amount had not been found. Subsequently, in further driving of the tunnel, sulphide ore was encountered in the lode material. Specimens of the last material taken from the tunnel were sent to the writer by Mr. Rodine and prove to contain both pyrite and arsenopyrite.

The Boulder lode is similar in many respects to the California quartz lode, on Goldbottom Creek—that is, it is a lode of the disseminated type—a mineralized body lying probably in a zone of shearing. Mr. Rodine says that the trend of the lode, or, in other words, of this zone of disturbance, is about N. 3° E. If this is the correct direction of the lode, it would appear that the tunnel has crosscut about 76 feet of the mineralized zone, and in striking the sulphide ore the tunnel is probably entering the higher-grade ore.

Assays have been made about every 10 feet in this tunnel, and these, known in a general way to the writer, are considered favorable in so large a body of mineralized rock. If the assays are reliable there is here evidently a good-sized body of low-grade ore. Yet the owners should do a great deal more prospecting on the lode, particularly drill-hole prospecting, to determine its width and extension before making preparations for a milling plant.

On the northeast side of Boulder Creek another tunnel 35 feet long has been driven on the Dakota lode, which embraces 13 claims. The country rock here is limestone, with a minimum of iron staining and practically no sulphides. Veins of white, opaque quartz and of calcite are present, but there seems to be little indication of any intense mineralization.

Bedrock is uncovered in a pit in the creek bed on claim No. 1 below Discovery, Boulder Creek. The country rock is an iron-stained schist, the cleavage of which strikes N. 60° W. and dips 30° SW. A fault zone trending N. 30° W. and dipping southwest cuts through the schist at this locality. A vein of the white quartz near by strikes N. 60° E. and dips steeply northwest. The fault zone is greatly iron stained and cut by limonitic stringers. This material pans gold, and some very rich pieces of gold-bearing white quartz have been taken from this locality.

An open cut on the northeast side of Boulder Creek farther downstream has exposed a good-sized ledge of the white quartz. This is chiefly of interest on account of the presence of pyrite and pyrrhotite together in the quartz, the pyrrhotite being much less plentiful in the Nome district than pyrite or arsenopyrite.

BURSIK & KERN.

Eight claims extending from northwest to southeast across the divide between Anvil and Dexter creeks are being prospected by T. Bursik and Louis Kern. The main development work consists of several open cuts, several shallow shafts, a 20-foot tunnel, and the main shaft, about 85 feet deep.

On one of the open cuts a limestone-schist contact is exposed, the country rock striking N. 55° E. and dipping 20° SE. The limestone is white and contains some lenses of white (bull) quartz. The schist is dark and micaceous. In the shallow shafts iron-stained schist and fractured and iron-stained quartz may be seen.

At an elevation of 900 feet, at the southwest base of King Mountain, a prospect tunnel 20 feet long has been driven. The schist country rock at this locality strikes northeast and dips 5° SE.

The main shaft is at an elevation of 700 feet, on the slope between Anvil and Dexter creeks. Over 100 assays of material taken from this shaft are said to have been made, showing values ranging from $2.50 to $3.25 a ton.

HINES.

A number of claims are being prospected by Arthur Hines. Five of these are on top of King Mountain and are known as the Royal group. Four others lie along the left bank of Dexter Creek. None of the Hines claims were visited by the writer.

ANVIL CREEK.

Along the northwest side of Anvil Creek, from the mouth of Specimen Gulch downstream to a point below Quartz Gulch, a number of open cuts and short tunnels have been made in the course of prospecting for gold lodes by different men.

About opposite the mouth of Specimen Gulch a tunnel has been driven by J. C. Widstead, exposing graphitic schist cut by calcite veinlets and pyrite stringers. Antimony ore is said to have been mined from this tunnel. A short distance downstream, where the trail goes up on the ridge to Glacier Creek, an open cut made by F. McIntosh exposes a fault zone. About 7 feet of lode matter lies between two faults, of which the upper strikes N. 40° E. and stands vertical and the lower strikes about north and dips 60° W. The lode matter between these two faults is a shattered graphitic and calcareous schist, cut by irregular quartz stringers, the whole intensely iron stained. A few feet farther west this fault zone is again exposed, showing a fault striking N. 50° E., with an indeterminate thickness of sheared and iron-stained schist on each side.

Below the mouth of Quartz Gulch there are three other open cuts, also opened by F. McIntosh. At the upper of these a vertical fault striking N. 20° E. is apparent. Both schist and vein quartz are here cut by the fault, and show pyrite mineralization. The second cut (downstream) shows both limestone and schist on the dump and, though caved, evidently points to a contact between these two rocks. The third cut is in limestone, which is shattered and veined with calcite.

About 300 feet downstream from the last-mentioned open cut, on the same side of Anvil Creek, a tunnel has been driven by G. Christophosen in the iron-stained schist. This is caved and inaccessible.

About 500 feet farther down Anvil Creek an open cut and a short tunnel belonging to Charles Olsen show a well-marked fault striking east and dipping 53° N. The schistose country rock is cut by white quartz stringers, but these are earlier than the faulting and its attendant mineralization. Stibnite occurs along this fault. Assays made of this material are said to show 50 per cent of antimony and $21.60 in gold and $2.05 in silver to the ton.

At an elevation of about 300 feet on the northwest side of Anvil Creek, where the Miocene ditch comes through the divide, a tunnel has been driven 150 feet by Hendrickson, Kotovic & Stipek. This tunnel is old, and the walls are covered with sediment, so that the structure is scarcely discernible. Caving has taken place in the rear of the tunnel. It is said that this tunnel goes 120 feet through a mineralized country rock carrying sulphides and that there is a particularly rich zone 15 feet wide in this mineralized belt, about 75 feet from the entry, which assays $11 to $12 a ton in gold.

On the southeast side of Anvil Creek opposite the tunnel a 30-foot shaft has been sunk by the same men. This shaft is inaccessible, but material on the dump shows the presence of mineralized schist and vein quartz. The sulphides are pyrite, arsenopyrite, and a little stibnite. The vein quartz carries feldspar.

CHARLES.

At an elevation of 900 feet on the left side of Cooper Gulch there is a caved-in shaft belonging to M. Charles. The country rock is an iron-stained limestone.

On the west side of Dry Creek, at an elevation of 525 feet, about where the valley opens out into the flats, Mr. Charles has driven a tunnel 25 feet long in the iron-stained crystalline limestone, which strikes N. 42° E. and dips 18° NW. Another tunnel 50 feet down the hill slope has been driven 15 feet in blue crystalline limestone, which has the same strike and dip. A fault striking N. 25° W. and dipping 68° NE. cuts the limestone in the tunnel, and a foot or more of calcite is present along the east side of the fault. The rock is iron stained, but no sulphides were observed.

HOMBURGER.

On Newton Gulch lode and placer claims aggregating more than 600 acres are owned by August Homburger. About a dozen shafts and two churn-drill holes have been put down on these claims. From these it appears that the country rock is largely schist, with beds of limestone and greenstone. The material taken from the shafts is iron stained and in some places mineralized by pyrite. Stringers of white, opaque quartz and veinlets of glassy quartz occur in the schist. The owner reports a mean value of $5 a ton in gold as the result of composite sampling.

OLSEN.

On the southeast side of Anvil Creek, midway between the mouth of Specimen and Quartz gulches, five lode claims extending in a direction about S. 25° W. are being prospected by Charles Olsen. The country rock at this locality is a graphitic schist, similar to that exposed by placer mining along the left-hand bench of Anvil Creek.

This graphitic schist strikes north and dips at varying angles to the east. White quartz veins standing nearly vertical cut the schist in a general N. 45° E. direction.

The property is being prospected by means of a 97-foot shaft from the bottom of which a 35-foot drift has been driven. It is evident from the description by the owner that the lode lies along a fault zone. The quartz in the lode is displaced by faulting. A little stibnite is reported from this lode. The owner reports an average value of $16 a ton for the ore from the shaft.

PETERSON & LAMOREAUX.

On the ridge between Anvil Creek and Snake River, southwest of Quartz Gulch, at an elevation of 650 feet, a big ledge of white, opaque (bull) quartz has been exposed by Peterson & Lamoreaux in an open cut and short tunnel. This body of quartz is 8 feet or more thick, strikes S. 45° W., and dips about 45°NW. It is heavily iron stained. The vein is not clean cut but shows stringers going off into the black schist country rock. Strongly developed fractures striking N. 35° W. are present in the quartz, as well as other irregular fractures and faults. This quartz has the appearance of having suffered considerable metamorphism and is probably an old quartz vein formed prior to the gold mineralization of the region. It is reported that galena was found disseminated in some of this quartz. A near-by shaft, about 40 feet deep, is filled with water.

STIPEK & KOTOVIC.

A number of claims on Rock Creek and on the divide between Rock and Glacier creeks are being prospected by W. Stipek and J. Kotovic. On the east side of Rock Creek, at an elevation of about 200 feet, about 25 feet above the creek bed, there is a shaft 76 feet deep, on the dump from which are pyritized schist and white quartz. The shaft is filled with snow and inaccessible. A 70-foot crosscut is said to have been made at the bottom of the shaft 35 feet in opposite directions, exposing a ledge of mineralized rock. This ledge trends S. 5° W. The dump from this shaft is said to assay $8.50 a ton in gold, and stringers rich in sulphides are said to have assayed as high as $150 a ton. It is a significant fact, in view of what has already been said concerning the scarcity of true gold quartz, that no quartz is present with these stringers.

Just below this shaft, on a level with the creek, a prospect tunnel has been driven 120 feet into the hill, crosscutting the lode. Just inside the entry the tunnel cuts through a 12-foot vein of the white opaque quartz, which is greatly shattered and iron stained. A mill run on this material has shown it to contain 250 pounds of concentrates to the ton of rock milled and $2.65 a ton in free gold. The concentrates, which are chiefly arsenopyrite and pyrite, are said to assay from $48 to $65 a ton in gold. Hence the total value of the mineralized quartz would be about $8.25 a ton.

Beginning at a point 15 feet from the entry and continuing to the face, sulphides are plentiful in the mineralized schist and shattered white quartz. Arsenopyrite is particularly abundant. A fault, striking east and dipping steeply to the north, cuts across the tunnel at the beginning of the sulphide zone. It is said by the owner that the schist in the mineralized zone carries more gold than the mineralized quartz.

About 75 feet downstream, on the same side of Rock Creek, another tunnel has been driven 40 feet, showing in part the same general section, including the large vein of white quartz above described. It appears, therefore, that the zone of mineralization has a general northeasterly extension.

On Sophie Gulch, above the scheelite deposits, another prospect tunnel belonging to the same owners has been driven. This is 65 feet long, but is caved and inaccessible. A short open cut below the tunnel, however, shows the presence of mineralized country rock.

NUGENT.

At an elevation of 300 feet on the southeast side of Rock Creek, at the level of the creek, the so-called Nugent tunnel has been driven 150 feet into the hillside. The country rock is a much iron-stained schist striking N. 20° E. and dipping 25° SE. It is cut by many quartz stringers which are reported to carry considerable gold. These quartz veins strike consistently N. 45° E. and dip steeply to the southeast. No recent work has been done in this locality, and the owner was not present to give any first-hand information.

NEW ERA MINING CO.

The New Era Mining Co. owns seven lode claims, known as the Big Four group, on Snow Gulch, a tributary of Glacier Creek. The New Era mine has been described by Chapin.[1] Little recent work has been done at this property. The principal development work consists of a 315-foot tunnel, driven to crosscut the lode. This was inaccessible at the time of the writer's visit and, having been described by Chapin, will not be further considered in this paper.

A shaft 60 feet deep has been sunk on the Big Four claim, east of Snow Gulch, at an elevation of about 500 feet. This likewise was inaccessible, but the writer was given information concerning conditions underground by Capt. Fred West, one of the owners. The country rock at this point is limestone, which is cut by numerous quartz veins and stringers ranging from a fraction of an inch to 18 inches in thickness. These stringers strike N. 65° E. in a zone about 60 feet wide. At the 30-foot level a drift has been driven 32 feet in a direction about N. 65° E., along the lode, and another S. 25° E., to crosscut the lode. The quartz is said to be true gold quartz—that is, little iron stained, with numerous open spaces, unshattered, and carrying crystalline gold. It resembles the so-called "water quartz," as it is termed by the miners of the Fairbanks district, or the true vein quartz of that district.

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[1] Chapin, Theodore, Mining on Seward Peninsula: U. S. Geol. Survey Bull. 592, pp. 400–401, 1914.

A short distance downhill from this shaft schist begins, and the mineralized zone continues into it. Schist strikes N. 15° E. and dips 30° E. The true vein quartz is said to be lacking in the schist, but there are parallel joints or slips that strike N. 55°-60° E. and dip about 65° NW. Some of the old white quartz lying along these joints is heavily iron stained with red ocher. The schist itself along the lode extension is iron stained and otherwise mineralized and is said to constitute a body of commercial ore.

GOLDEN EAGLE AND GOLD BUG.

The Golden Eagle and Gold Bug claims, owned by Capt. Fred West, are on the east side of Snake River about halfway between Mountain Creek and Snow Gulch, at an elevation of 400 feet. The development work consists of a tunnel 125 feet long, driven along a 6-foot vein of iron-stained, shattered quartz. The country rock, which is schist at this locality, strikes N. 32° W. and dips 25° SW. The quartz vein, which strikes N. 70° E. and dips 45° SE., cuts across the cleavage of the schist and is said to be traceable 1,500 feet at the surface. Some iron sulphides are present in the quartz, and assays taken at the breast indicate rather high grade ore, the extent of which, however, is not known.

JORGENSEN.

The Eureka and Borasco claims, at the head of Mountain Creek, a tributary of Snake River, are being prospected by A. C. Jorgensen. The development work on these two claims was of special interest to the writer because it shows clearly that the gold mineralization is absolutely independent of the presence of gold quartz.

The mica schist country rock strikes north and dips 28° E. It is cut by veins and stringers of the white vein quartz, somewhat irregular in character but striking in a general way about N. 60° E. and standing about vertical. A fault—in reality a fault zone about 1 foot thick—striking N. 65° W., with a high northeast dip, cuts both schist and quartz veins. All the schist in the vicinity is iron stained, but this feature is particularly evident near the fault, where the country rock is heavily charged with arsenopyrite. The hematitic material along the fault is a granulated iron-impregnated schist which pans free gold. Joint planes striking N. 30° E. and dipping 70° NW. are present in the schist and are much iron stained. They probably afforded a channel for the transmission of the auriferous solutions from the fault zone out into the adjoining schist.

Arsenopyrite is the chief sulphide present, pyrite being subordinate. The sulphide-bearing schist gives exceptionally good returns in gold. It is believed that a large proportion of the gold is combined with the sulphides. The free gold in the hematitic gouge is fine, even grained, and much discolored by iron. Scheelite is also found in and along one of the shattered, iron-stained white quartz veins.

The owner of these two claims plans to build a homemade 3½-foot conical tube mill and treat the ore in a small way, saving the free gold on plates and shipping the concentrates.

LABAY & MEEGAN.

The Labay & Meegan gold quartz lode is in the basin of Daniels Creek, northeast of Bluff, in the Solomon district. The writer was not able to visit this property but gained a general idea of conditions at this locality by conversation with Mr. L. A. Labay.

According to description, the property includes 16 or more lode claims, staked from north to south in groups of three. There are three lode systems extending in a north-south direction, known as the Sea Gull, Idaho, and Esquimeaux lodes, named in order from west to east. Two of these, the Idaho and Esquimeaux, coalesce along the southeast side of Daniels Creek.

The Sea Gull lode is said to be 37 to 39 feet wide and appears to be a mineralized zone in schist and quartz. This lode system strikes north and dips steeply to the west. The Idaho lode is reported to be 150 feet wide and likewise strikes approximately north and dips steeply west. Between the Sea Gull and Idaho lodes lies 200 feet of black schist. From data given to the writer by Mr. Labay it appears that these lodes contain a large body of low-grade commercial gold ore.

The present developments consist of a 100-foot tunnel on the Idaho claim, with a 40-foot winze at the breast and a 50-foot crosscut at the bottom of the winze. A 50-foot timbered shaft is also open on the Idaho No. 1 claim and a similar 75-foot shaft on the Idaho No. 2. There are a number of other prospect shafts, some timbered and others untimbered, most of which are caved. The owners are now arranging for the installation of a mill on the property.

TUNGSTEN.

SOPHIE.

The property known as the Sophie lode, on Sophie Gulch, a tributary of Rock Creek, consists of one patented placer claim and two lode claims. Residually weathered tungsten ore was mined here by placer operations in 1916. The following notes are not intended as a final analysis of the conditions of mineralization but merely as facts evident from the field examination. The results of microscopic work on this lode will be included in a later report.

The country rock at this place is an iron-stained, thin-cleaving, foliated mica schist, the cleavage of which, measured at one place in the pit, strikes north and dips 23° E. It shows also a vertical jointing trending N. 35° W. Many well-developed fissures are present, striking N. 45° E. and nearly vertical or dipping steeply to the northwest. These are filled with iron-stained shattered quartz. Such veins range in thickness from a fraction of an inch to a foot or more. There is great irregularity in these quartz stringers, most of them thickening in places and thinning in others; also stringers run out into the country rock. Iron-stained fault planes striking N. 18° W. and dipping 54° E. cut both the country rock and the quartz stringers, and along these there is little or no quartz but considerable iron-stained gouge material.

The scheelite occurs for the most part along the sides of quartz stringers and disseminated in the mica schist. Locally the scheelite is present in the quartz. It is reported that gold occurs in the iron-stained schist outside of the zone of scheelite mineralization, but no gold is reported to have been found in the scheelite-bearing rock. Besides scheelite, however, arsenopyrite, pyrite, and galena are found in the form of later veinlets definitely cutting the quartz.

It is said by the owners that the belt of scheelite mineralization is about 50 feet wide and has so far been traced about 500 feet in each direction from the open cut. The trend of this zone appears to be that of the iron-stained quartz veins and stringers—that is, about N. 45° E. The northwest side of the lode is reported to carry more scheelite than the other side. Two shafts—one 32 feet deep, northeast of the open cut, and the other 28 feet deep, southwest of the cut—have been driven to ascertain the value of the ore along the lode. It is said that these shafts show a higher content of scheelite in depth than at the surface.

LOST RIVER.

The Lost River tin mine, on Cassiterite Creek, a tributary of Lost River, in the York district, is a potential source of tungsten. Wolframite, an iron-manganese tungstate, is an essential constituent of the lode and may perhaps be present in an amount as great as 50 per cent of the cassiterite. When eventually this lode is worked the wolframite should constitute a valuable part of the product.

MISCELLANEOUS LOCALITIES.

Several other small tungsten lodes in Seward Peninsula have been worked by placer-mining methods. These include the lode on Twin Mountain Creek, the Lynx claim, on the north side of Glacier Creek, and another small lode on the divide between Glacier and Rock creeks.

ANTIMONY.

SLISCOVICH.

No work was in progress at the Sliscovich mine at the time of the writer's visit, but the mine was entered and an examination made of the antimony ore in place. At the end of the main adit, about 300 feet from the tunnel entry, an inclined shaft has been sunk on the vein, which has a general northeast strike and dips 45° NW. At about the 25-foot level in this incline a drift has been driven to the southwest, and from this drift the antimony ore was apparently taken. Below this point a good deal of caving has occurred in the incline.

At the 25-foot level the quartz vein strikes N. 45° E. and dips 48° NW. The attitude of the country rock, which is schist, is nearly horizontal, a measurement at one place on the cleavage giving a strike of N. 55° E. and a dip of 5° NW. The quartz vein is 3 feet thick in this drift and has a smooth, slickensided hanging wall and gouge along the footwall. The antimony ore (stibnite) occurs as lenses in the quartz, which is much shattered and iron stained. Plainly the quartz vein has been reopened and the stibnite deposited in the shattered vein. On the 25-foot level the body of stibnite is 1 foot thick and contains much glassy quartz, which accounts for the low percentage of stibnite reported from the last shipment of ore.

HED & STRAND.

The Hed & Strand mine is near the head of Lost Creek, a tributary of Stewart River, at an elevation of about 1,250 feet. The present developments consist of a tunnel driven southeast 250 feet into the hillside, a drift for 100 feet to the northeast and 140 feet to the southwest at 90 feet from the entry, and another drift 170 feet to the northeast, at 190 feet from the entry. The tunnel intersects the vein 90 feet from the entry. At this point the vein is about 4 feet thick and consists of white quartz and stibnite. The antimony occurs as a body 2 feet thick along the footwall. The vein strikes

N. 45° E. and dips 48° NW. but is irregular, thickening and thinning, and is offset slightly by numerous slips. At the end of the northeast drift, which starts 90 feet from the entry, the vein consists of two thin seams of stibnite with about 2 feet of crushed schist and gouge lying between them.

From the first drift southeast in the main tunnel some interesting structural data may be obtained. The strike of the schist country rock is N. 15° W. and the dip 15° E. Numerous faults cut across the tunnel, striking in a general northeasterly direction and dipping as a rule conformably with the antimony vein—that is, northwest. Several measurements on these faults were as follows: Strike N. 50° E., dip 58° NW.; strike N. 45° E., dip 75° NW.; several striking about N. 45° E., with varying degrees of dip to the northwest; one striking northeast and dipping steeply southeast. One of these faults, striking N. 45° E. and dipping 75° NW., which shows in the main tunnel 190 feet from the entry, cuts through and displaces a vein of white quartz, that stands vertical and strikes N. 52° W. The quartz is offset 2 feet along the tunnel wall. In general these fault planes are merely iron stained and slickensided, but here and there one carries a thin seam of clear granular quartz.

Most of the stibnite is of high grade, but "ore of lower grade, consisting of stibnite, pyrite, and vitreous quartz, also occurs in the deposit."[1] The vitreous quartz resembles the quartz which occurs sparingly along the fault planes, as above described. No gold is reported from the stibnite in the mine, but a little gold is present in the quartz and schist in the vein and along the walls.

Shipments of antimony ore were made from the Hed & Strand mine in August and October, 1915, and in June, 1916. In all, 106 tons of ore has been mined and shipped. Of the last shipment, consisting of 71 tons, only 19 tons has yet been sold.

At the forks of the creek, upstream from the mine, the stibnite crops out in a vein about 1 foot thick, with a footwall of the white, opaque quartz. At another locality in the creek near by the stibnite lies in two narrow stringers, separated by about 2 feet of similar white quartz. This quartz is said to assay as high as $6 a ton, and gold to the value of $2 a ton is said to be present in the stibnite at this point.

A body of granitic rock, considerably metamorphosed, crops out on the ridge at the head of Lost Creek, and this also is reported to show on assay a low content of gold.

CHRISTOPHOSEN.

The Christophosen property is at an elevation of 1,500 feet on Waterfall Creek, a tributary of Last Chance Creek, in the Snake

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[1] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, p. 56, 1916.

River drainage basin. The property consists of four claims, known as the Bunker Hill, Monitor, Mabel, and Isabel.

The principal development work consists of two tunnels and a number of open cuts. The upper tunnel is 105 feet long and the lower one 270 feet long. The tunnels are said to intersect a stockwork of iron-stained schist and quartz in which the stibnite occurs as lenticular masses. None of the antimony stringers are over 12 inches in thickness.

In the open cuts it is apparent that a shear zone, striking about N. 20° E., runs through the property. The attitude of the faults is about vertical. This zone is about 100 feet thick and is heavily iron stained and mineralized by pyrite, pyrrhotite, stibnite, and gold. In one of the open cuts a vein of massive white quartz from 1 to 3 feet thick is intersected and offset by the shear zone. The quartz is mineralized by sulphides, including stibnite. This vein is conformable with the cleavage of the schist country rock, which strikes N. 60° E. and dips 57° NW. It is confidently believed by the writer that this body of white, opaque quartz, like numerous others described in this paper, had no direct connection with the mineralization, being present long before the mineralization took place.

About 2½ tons of high-grade stibnite has been mined at this property and sold. This stibnite assays over 58 per cent antimony and carries also some gold and silver. Assays of the crushed schist and quartz in the shear zone also show a little gold.

GRAY EAGLE.

The Gray Eagle antimony claim is in the Solomon district, on the north side of Big Hurrah Creek, three-fourths of a mile upstream from the railroad and about 200 feet from the creek. The country rock is schist. Mining has been done on a stringer of stibnite about 18 inches wide that follows the right-hand bench and dips steeply south. Little or no quartz is present with the antimony ore. The stibnite is of very high grade, assaying 63.7 per cent of antimony. It contains no lead or zinc and only a trace of arsenic.

Four tons of antimony has been mined from this property, of which 3 tons was mined and shipped in the fall of 1915. One ton mined in the spring of 1916 has not yet been shipped from Nome.

PETERSON & LAMOREAUX.

At an elevation of 550 feet on the west side of Anvil Creek southwest of Quartz Gulch there is a caved shaft with iron-stained schist on the dump. About 1,500 pounds of stibnite is said to have been mined from this shaft by Peterson & Lamoreaux, but this ore was never shipped, owing to the subsequent drop in the price of antimony.

WIDSTEAD.

The Widstead tunnel, on the northwest side of Anvil Creek about opposite the mouth of Specimen Gulch, is referred to on page 430. Three tons of stibnite is said to have been mined from this tunnel.

MISCELLANEOUS LOCALITIES.

Brooks[1] has noted a number of reported occurrences of stibnite on Seward Peninsula, as follows:

1. East of Nome River, on the divide between Mineral and Osborn creeks. This is probably what is known as the Nelson property, at the head of Bonita Creek, a tributary of Osborn Creek. A shaft 15 feet deep has been sunk on this property. The stibnite is said to be exceptionally pure and is reported further to carry abnormally large quantities of gold.
2. The California quartz lode on Goldbottom Creek. Reference is made to this lode on page 426.
3. On Last Chance Creek. This is assumed by the writer to be the Christophosen property (p. 438).
4. In the quartz veins in the Solomon-Casadepaga region.
5. At the head of Tin Creek, in the York district.
6. On the west side of Brooks Mountain, in the York district.
7. In the Omalik mine, a silver-lead mine in the upper basin of Fish River, in the Council district.

To these may be added the occurrence of stibnite in the Boulder lode, on Boulder Creek, described on page 427.

COPPER.

WARD.

The Ward property is about 3½ miles north of west of Kougarok Mountain, in the Kougarok district. The eight claims that constitute this property lie between Bismark and Star creeks, tributaries of Quartz Creek, which is the head of the South Fork of Serpentine River.

The development work consists of a number of open cuts and shallow shafts. From a description of the property given by the owners it appears that the lode is an impregnated zone lying along or near a limestone-schist contact. The schistosity of the rocks is said to strike N. 30° W. and dip northeast. The width of the ore body is not apparent from the present workings.

The commercial ore consists of malachite and azurite in about equal amounts. A little chalcopyrite is also reported. Quartz is the main gangue mineral, but calcite and blue fluorite occur as float in the vicinity.

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[1] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, pp. 57–59, 1916.

The following table, published with the permission of the owner, gives all available information concerning the copper shipments made from this property to date:

Copper ore shipped from Ward property, 1906–1916.

Year.		Quantity.	Copper content (per cent).	Value.
1906	tons	8	41	$1,200.00
1907	do	8	41	1,200.00
1913	do	14	30.34	1,400.00
1916	pounds	18,947	....	981.12
				4,781.12

WHEELER.

The Wheeler copper claims are at the head of several small tributaries of Iron Creek on the west side, below the mouth of Canyon Creek. The principal development work to date consists of a tunnel 60 feet long and a shaft 80 feet deep. Outcrops on the hill southwest of the claims show about 9 feet of quartz stained with malachite and several stringers of malachite. Ore taken from the shaft shows both chalcopyrite and bornite in small quantities, with a surficial oxidation of malachite. The strike of the zone of mineralization is said to be about northeast. The shaft is now filled with water, and the tunnel is frozen. It is reported that several tons of ore has been shipped from this property.

IRON CREEK-KRUZGAMEPA RIVER DIVIDE.

Other copper mineralization along the divide between Iron Creek and Kruzgamepa River has been described by Smith[1] as follows:

> Between Iron Creek and the broad flat drained by tributaries of the Kruzgamepa and of the Niukluk there is a ridge of heavy white limestone underlain by chloritic and feldspathic schists. From the scattered evidence collected in a hurried examination it appears that the limestone is very considerably folded, but that the major structure is nearly flat. The limestone would appear to be a continuation of the limestone already described as forming the western margin of the Solomon and Casadepaga quadrangles. In those areas the contact with the underlying schist seems to have been a zone of mineralization. In general the mineralization is sparsely disseminated, but in places there are stringers of ore which tempt prospecting.
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> The greatest amount of prospecting for copper in this contact zone has been at the headwaters of Sherrette Creek, a tributary of the Kruzgamepa. At one place about 4 miles east of the mouth of Iron Creek an inclined shaft has been

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[1] Smith, P. S., Investigations of the mineral deposits of Seward Peninsula: U. S. Geol. Survey Bull. 345, pp. 242–243, 1908.

sunk on a mineralized zone 5 feet in width. The footwall is a silvery-gray chloritic schist destitute of feldspars. The hanging wall is ill defined, and the width of the ore would have to be drawn on a commercial basis. The footwall is so poorly exposed that its character may be due to alterations effected by the mineralizing solutions, but it is believed that it is not a schist derived from an igneous rock.

The ore so far disclosed consists chiefly of malachite, but there are also some copper sulphides, mainly chalcopyrite, with only a subordinate amount of bornite. The stringers are very narrow, and no commercial ore has yet been discovered. All over the hill, however, may be found fragments showing copper stains. This has given rise to the popular belief that the belt of mineralization is very wide. If, however, the interpretation that the ore occurs near the schist-limestone contact is correct and if this contact forms a more or less flat surface, with local wrinklings here and there, it seems more likely that the width of the mineralized area is not very great and therefore that the chance of finding valuable lodes is not promising except in those places where the mineralization, instead of being disseminated over a large area, has been more restricted.

All the float or ledges on the higher ground north of Iron Creek which show copper carbonate stains carry that mineral in the form of malachite. Lower down the slopes, near the upper branches of Left Fork, a tributary of Iron Creek, there is a copper lead where malachite is almost wanting and where the copper carbonate occurs in the form of azurite. The reason for this difference in character is not known. At this place only a small amount of exploration has been done, and the ore so far developed is not found in commercial quantities.

WORCESTER.

Five lode claims about 3 or 4 miles southeast of Kougarok Mountain, in the Kougarok district, are owned and have been prospected by William Worcester. Little is known of this property, but it was reported to the writer that the copper ore is malachite and azurite. Lead ore in the form of galena is said also to be present.

MISCELLANEOUS LOCALITIES.

Copper ore is reported by Mr. G. Christophosen to be present on the mountain at the head of Waterfall Creek, in the vicinity of the Christophosen antimony claims. The ore is said to be chalcopyrite, with azurite and malachite. Galena is also reported.

On Twin Mountain, at the head of Twin Mountain Creek, copper has been discovered and the area staked as the Ruby and Golconda claims. A tunnel has been driven to prospect this deposit but was inaccessible at the time of the writer's visit. The deposit appears to be localized in a shattered quartz vein. The copper minerals are chiefly malachite and azurite, but chalcopyrite is also reported to be present.

Four other copper prospects on Seward Peninsula have been described by Smith.[1] These were located as follows:

1. On the ridge between Copper and Dickens creeks, at the head of Nome River.

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[1] Smith, P. S., op. cit., pp. 241, 244.

2. In the upper basin of Koyuk River.
3. On Dexter Creek.
4. On Mount Dixon and in the Moonlight Creek divide, in the Solomon district.

TIN.

LOST RIVER.

The Lost River tin mine, comprising the Cassiterite and Ida Bell lodes, is located on Cassiterite Creek, a tributary of Lost River, in the York district. Prospecting and development work have been in progress on this property for a number of years. Knopf[1] and Eakin[2] have visited this mine and have described the lode system and the character of the mineralization in some detail.

An option on the property was assumed in 1916 by W. W. Johnson and associates, who further prospected and developed the mine during the summer. A 50-ton ball mill, together with jigs, concentrators, etc., was shipped to Teller for use in making test runs on the tin ore, to determine the average tin content.

MISCELLANEOUS LOCALITIES.

Another tin lode, farther downstream on Lost River, is known as the O'Brien lode. The lode is said to be in a rhyolitic dike in limestone. Development work was being done on it in 1916.

The Empire Tin Mining Co. has 33 (?) claims on Cape Mountain, about 2½ miles from Tin City. The writer was informed that the lode here consists of an ore shoot about 18 feet wide, more or less parallel to a limestone-granite contact. A mill at Tin City with three stamps, operated by gasoline engines, is not in use. No recent development work has been done on this property.

The Percy lode, farther up on Cape Mountain, is owned by Ludlow Botts. It is understood that this lode is in or near a small rhyolitic dike, which invades the limestone country rock. The property is being developed by open cuts, but most of the recent work has been in the nature of assessment work.

The property of the United States Tin Mining Co. is likewise on Cape Mountain. This company owns a 10-stamp mill at Tin City, equipped with card tables and driven by gasoline engines. The mill is not in operation. A tunnel, driven in granite, is now closed.

Denny Bros. own a number of tin claims on Potato Mountain. The lode is said to be connected with several rhyolitic dikes that cut a body of calcareous slate. The development work consists principally of a tunnel and a shaft, the former opened recently.

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[1] Knopf, Adolph, Geology of the Seward Peninsula tin deposits: U. S. Geol. Survey Bull. 358, pp. 48–50, 1908.

[2] Eakin, H. M., Tin mining in Alaska: U. S. Geol. Survey Bull. 622, pp. 84–88, 1915.

IRON.

MONARCH GROUP.

The Monarch group of fifteen patented and three unpatented claims lies on the divide between Sinuk River and Washington Creek, at the head of a small tributary of Sinuk River known as Iron Creek. This and four other groups of iron claims near by have been described by Eakin,[1] and little development work has been accomplished since the time of his visit in 1914. The writer examined with considerable care the outcrops and development work on the Monarch claims and, so far as concerns their economic possibilities, has little to add to the generalizations and recommendations made by Eakin.

The country rock is limestone, which has been brecciated and replaced by limonite. Hematite is present only as a subordinate constituent. A specimen of the ore taken from a trench at the head of Iron Creek shows on a polished surface massive limestone with numerous angular inclusions of iron-stained limestone, residual fragments of the shattered country rock. Pyrolusite, in places intergrown with calcite, is present in veinlets that cut the limonite and the replaced limestone. These relations and the probable genesis of this iron deposit will be discussed more fully in a later paper on the iron resources of Alaska. For this report it is sufficient to say that the iron ore now exposed on the ridge and in Iron Creek is a residual concentration, a surficial enrichment of an underlying lode. The iron content of this lode at depth can not be judged from the surface indications; in fact, it is entirely possible that this deposit is only a surface capping, or "iron hat," covering some other metalliferous deposit. The occurrence of galena and sphalerite with limonite in the Galena group near by, the presence of similar limonitic material in considerable amount in a silver-lead lode in the Inmachuk basin, and the constant association of limonitic material and other iron minerals with most of the gold lodes on the peninsula might be cited as evidence of this possibility.

The best showing of iron ore is in a saddle on the ridge at the head of Iron Creek, at what is designated by Eakin the "east gap," in contradistinction to the "west gap," a similar saddle a short distance to the southwest. At this locality two shallow trenches aggregating 350 or 400 feet in length have exposed a continuous body of iron ore, chiefly limonite with a small amount of hematite. This limonitic ore is botryoidal in character but inclined to be porous, with fair-sized open spaces. It is considered by the owners of the property to be the best iron ore on the property. An analysis of this ore[1] shows the content of iron and manganese to be respectively 54.81 and 1.08 per cent. Phosphorus is low, being only 0.057 per cent; sulphur is present only as a trace; and titanium is entirely absent.

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[1] Eakin, H. M., Iron-ore deposits near Nome: U. S. Geol. Survey Bull. 622, p. 361, 1915.

Limonite was seen in a number of other trenches, pits, and open cuts examined by the writer on the different claims, but this surficial development work does not afford a basis for any estimate of the amount of iron ore available for mining. It seems to the writer that an accurate estimate could be made only after blocking out the ore by a comprehensive system of drilling. At all events, scientific prospecting of this lode, to gain a knowledge of its character in depth, should be a necessary preliminary step to any extensive preparations for mining.

GALENA GROUP.

The Galena group, consisting of nine claims, is about 2 miles southwest of the Monarch group on the divide between Sinuk River and Washington Creek. These claims, though prospected chiefly for their iron content, have also surface indications of both lead and zinc, in the form of galena and sphalerite.

It appears that the ore-bearing solutions have followed in large measure one or more of a system of joint planes in the country rock. On the Sunrise claim, one of this group, the country rock is crystalline limestone, the cleavage of which strikes east and dips 25° S. This limestone is cut by a number of joint planes, the more prominent of which had the following strikes and dips: N. 40° E., 65° NW.; N. 80° E., 70° N.; N. 15° W., 90°. Disseminated galena in a quartz gangue occurs along the vertical joint plane. This ore is said to show considerable values in gold.

An open cut on the Oso claim shows disseminated sphalerite, with a little pyrite, in the crystalline limestone. The extent of the zinc mineralization is not known. In a pit at another locality on the Oso claim the same system of jointing as above described was exposed, and vein quartz, with some iron-stained vein material, occurs along a joint plane striking N. 10° W. and dipping 75° N. Lilac-colored fluorite was also seen in this pit, but its exact relation to the mineralization could not be determined.

On the Fox and the Williams claims disseminated galena accompanied by quartz was observed in limestone and calcareous schist.

Considerable botryoidal limonite was seen on the dump at a prospect on the Kentucky claim.

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[1] Eakin, H. M., Iron-ore deposits near Nome: U. S. Geol. Survey Bull. 622, pp. 361–365, 1915.

OTHER CLAIMS.

The Mogul, American, and Cub Bear are the three other groups of iron claims in the Sinuk district. No recent work has been done on these claims, and they were not examined by the writer. Limonitic iron ore is also reported from Tub Mountain, on the ridge between Rulby Creek and Sinuk River.

SILVER-LEAD.

Six silver-lead lodes have been reported on Seward Peninsula, but none of these have been visited by the writer. These are as follows:

1. The Omalik mine, in the eastern part of the upper basin of Fish River, in the Council district, has been described by Mendenhall[1] and Smith.[2] The mine is now idle.
2. A silver-lead lode on Fish River, about 5 or 6 miles above the mouth of Niukluk River, in the Council district, is said to have been worked sporadically for several years. Some silver-lead ore is reported to have been mined in 1915. Cinnabar is also present at this property, and it is reported that a number of flasks of mercury have been produced annually for several years past.
3. A silver-lead lode in the Inmachuk basin, in the Fairhaven district, was being prospected in 1916. A specimen of this ore, in possession of the writer, shows galena (said to be silver bearing), together with limonite, magnetite, and a little pyrite.
4. A silver-lead lode owned by G. Christophosen is on the north side of Last Chance Creek, a tributary of Snake River, about half a mile above the mouth of Waterfall Creek. The prospect consists of two lode claims. A tunnel 70 feet long has been driven to prospect the lode. The ore body is said to be 4 feet thick and consists of galena, with some pyrite, in a gangue of quartz. The lead ore carries gold and silver. Stibnite is also reported to be present.
5. A galena prospect on Kruzgamepa River, near the mouth of Iron Creek, has been described by Smith.[3]
6. A number of silver-lead deposits on Brooks Mountain, in the York district, have been described by Knopf.[4]

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[1] Mendenhall, W. C., A reconnaissance of the Norton Bay region, Alaska, pp. 213–214, U. S. Geol. Survey Spec. Pub., 1901.

[2] Smith, P. S., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, pp. 130–133, 1911.

[3] Smith, P. S., Investigation of the mineral deposits of Seward Peninsula: U. S. Geol. Survey Bull. 345, pp. 246–247, 1908.

[4] Knopf, Adolph, The mineral deposits of the Lost River and Brooks Mountain region, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 345, pp. 269–271, 1908.

ZINC.

CHRISTOPHOSEN.

A zinc prospect consisting of two claims owned by G. Christophosen is on the ridge between Penny River and the head of Oregon Creek, at an elevation of 1,600 feet. The prospect lies N. 64° E. from the mouth of Nugget Creek.

The ore occurs in a small saddle on the ridge, in a narrow band of limestone country rock. A short distance away, on both sides of the saddle, the country rock is schist, and this rapid alternation of limestone and schist is a characteristic geologic feature in this vicinity. The strike of the country rock is N. 30° E., and the dip about 30° SW. There appears to be no well-defined vein, but instead an iron-stained zone of mineralization, which trends approximately S. 8° E. The lode was located originally by float in the valley of Penny River. Development work consists mainly of a caved shallow shaft.

The ore is sphalerite, with a little pyrite, in a quartz gangue. Two kinds of quartz are present—the white, opaque variety and the clear, vitreous quartz. The latter appears to be either contemporaneous with the ore deposition or at least closely connected with it genetically. The ore is said to carry also some gold.

NELSON.

On Steep Creek, a tributary of Goldbottom Creek, at an elevation of about 1,050 feet, is the Nelson prospect tunnel, driven 55 feet N. 55° E. into the hill on the east side of the creek. The country rock is limestone striking N. 15° W. and dipping 18° W. A well-developed vertical joint plane strikes in same direction as the tunnel. The tunnel was full of water at the rear, and no one was seen on the property.

About 20 feet above the tunnel a small lead-zinc stringer was observed in the limestone. A little pyrite is also present with the galena and sphalerite.

Sphalerite is also reported in association with metalliferous lodes in other parts of Seward Peninsula.

BISMUTH.

The following extract from a report by Moffit[1] gives the only information so far collected concerning the bismuth lodes on Seward Peninsula:

> It has been known for a number of years that bismuth is present on Charley Creek, a tributary to Sinuk River from the south. It was first found in the

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[1] Moffit, F. H., Geology of the Nome and Grand Central quadrangles, Alaska: U. S. Geol. Survey Bull. 533, p. 138, 1913.

sluice boxes at the lower end of the creek, and later the float was discovered farther up and traced to its source. On the east branch of Charley Creek, at a point about 1,000 feet from the forks and at an elevation of 950 feet above sea level, two parallel quartz veins appear near the stream bed and have been found to carry the bismuth. These two veins are about 12 inches and 8 inches in thickness and are separated by 16 to 18 inches of schist. They occur in strike joints dipping 50° to 60° and may be traced on the surface for only a short distance because of the covering of loose slide rock. At one place they are offset about 8 to 10 inches by a small fault. The proportions of bismuth seen in the veins is small, but some boulders found in the stream below show a larger amount. Up to the present time little has been done toward prospecting the veins.

A number of bismuth claims on Charley Creek are now held by Homburger & Shoemaker, but no recent development work has been done on them.

GRAPHITE.

Graphite deposits on Seward Peninsula have been known for a number of years and have been described and discussed by Moffit,[1] as follows:

> Graphite is abundant in some of the black schist beds belonging to the Nome and Kigluaik groups and gives them their characteristic color but is not known in a form to make it of economic importance within the Nome and Grand Central quadrangles. Just north of the Grand Central area, however, in the headwater areas of Grand Central River and Windy Creek, especially in the vicinity of the divide between these two streams, are graphite deposits of considerable size. Their occurrence, as well as that of graphite on the north side of the Kigluaik Range west of Cobblestone River, has been known for a long time, but only recently have they received especial attention from prospectors.
>
> A sharp ridge made up of biotite schist striking east and west and intruded by dikes and sills of coarse granitic rock or pegmatite rises on the south from the saddle between the Grand Central and Windy Creek. Some of the schist is highly graphitic, the graphite appearing as abundant small scales on the cleavage surface and much of it not being distinguishable on casual examination from flakes of biotite. Locally graphite is segregated in beds or much flattened lenticular masses that conform in direction with the schist cleavage and reach thicknesses of 6, 8, or even 18 inches. These beds include thin layers of schist containing numerous large garnets and much quartz. The raw graphite found at this place is heavier than the higher grades of graphite, owing to its included quartz.
>
> The sills and dikes of pegmatite cutting the schist also contain graphite, which is associated with them in such a way as to suggest a close relationship between the intrusives and the graphite. Graphite appears to be an original mineral in the pegmatite as well as to be associated with it in the schist. At one place about 8 inches of solid graphite is included between a pegmatite sill and the overlying schist. The steep slopes of the mountain are strewn with graphite fragments, which, owing to the fact that they are much lighter in weight than either the schist or the pegmatite, appear more abundantly on the surface, especially in gullies where water has brought about a rough

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[1] Moffit, F. H., op. cit., 135–136.

sorting. One block, with dimensions of approximately 7 feet, 6 feet, and 30 inches, consists of about equal thicknesses of schist and apparently almost pure graphite.

The graphite-bearing schist extends eastward beyond the east fork of Grand Central River and westward across Windy Creek and the head of Cobblestone River to the region south of Imuruk Basin, in which the graphite is even more extensively developed than in the locality described and from which a number of commercial shipments have been made.

Two mining companies are now interested in the graphite deposits on the north side of the Kigluaik Range, west of Cobblestone River. The property of one of these, known as the Uncle Sam Alaska Mining Syndicate, is on Graphite Bay, an arm of Imuruk Basin, about 2 miles south of tidewater and 3 miles west of Cobblestone River. That of the other, known as the Alaska Graphite Mining Co., is between the Uncle Sam Alaska Mining Syndicate's claims and Cobblestone River.

According to information given to the writer by Mr. G. Christophosen, of Nome, the country south of Imuruk Basin in the vicinity of the graphite claims is a moss-covered gravel plain, barren of timber and sloping gently upward with a grade which increases from 5 per cent near Imuruk Basin to 10 per cent or more near the foothills. The graphite claims adjoin the foothills and are cut by numerous streams, which have exposed the graphite beds to view.

The graphite occurs in seams from 1 inch to 18 inches thick. All the deposits contain bunches and veinlets of quartz, but the graphite is said to be readily separable from these and is easily hand sorted. The graphite is claimed to be of good commercial character. A 200-pound sample from the claims of the Uncle Sam Alaska Mining Syndicate is said to have contained 60 per cent of graphite, 12.5 per cent of which is high-grade graphite flake comparable with the best commercial flake.

Shipments of 130 tons of graphite were made by the Uncle Sam Alaska Mining Syndicate in 1912, and 300 tons is now ready for shipment. The Alaska Graphite Mining Co. in 1916 employed seven men and mined 100 tons of graphite.

PLACER MINING ON SEWARD PENINSULA.

By J. B. MERTIE, Jr.

INTRODUCTION.

Placer mining on Seward Peninsula was favored in 1916 by an abundance of rainfall, which was rather evenly distributed throughout the summer and was never torrential. As a result, an adequate supply of water was available for mining operations, yet there was little or no damage done to the ditches through flooding.

Gold and tin were recovered, as in previous years, chiefly by placer-mining methods. In addition to these, however, two other metals, tungsten and platinum, were brought to light in 1916 as potential resources of the peninsula. One large scheelite lode and a number of smaller ones were located and worked, and scheelite was recovered elsewhere in placer operations. Placer platinum was found at two localities.

GOLD.

The placer gold on Seward Peninsula is recovered by dredging, by underground mining, and by open-cut work, including hydraulicking. It is estimated that in 1916 33 per cent of the gold was won by dredges, 18 per cent by underground mining, and the remaining 49 per cent by open-cut work.

DREDGES.

A total of 27 gold dredges were operating during the season of 1916, as compared with 31 operated in 1915. Seven of these were in the Nome district, nine in the Council district, five in the Solomon district, and two each in the Kougarok, Fairhaven, and Port Clarence districts. Several other dredges were either temporarily idle or in process of moving and reconstruction. Among these were the two gold dredges of the American Gold Dredging Co. on Anikovik River, which were to be moved to Swanson Creek, in the Agiapuk River basin, a short distance southeast of Mukacharni Mountain. The Johnson dredge, which had previously operated on Kugruk River, was to be moved during the winter of 1916–17 to Candle Creek, in the Keewalik basin. Ground was being prospected for dredging at four other localities on the peninsula. The following list gives by districts the operating dredges and the localities where the work was being carried on:

Dredges operated on Seward Peninsula, 1916.

NOME DISTRICT.

Arctic Gold Dredging Co	Hobson Creek.
Arctic Placer Mining & Milling Co	Bangor Creek.
Center Creek Dredging Co	Center Creek.
Ernst Alaska Dredge Co	Nome Beach.
Guinan & Ames	Glacier Creek.
Hastings Creek Dredging Co	Hastings Creek.
Julien Dredging Co	Osborn Creek.

COUNCIL DISTRICT.

Adams & Edin	Goose Creek.
Blue Goose Mining Co	Ophir Creek.
Flume Dredge Co	Crooked Creek.
Flume Dredge Co	Melsing Creek.
Northern Light Mining Co	Ophir Creek.
Oro Dredging Co	Elkhorn Creek.
Uplift Mining Co	Camp Creek.
Warm Creek Dredge Co	Warm Creek.
Wild Goose Mining & Trading Co	Ophir Creek.

SOLOMON DISTRICT.

Dredge (formerly Seward Dredging Co.)	Solomon River.
Kimball dredge	Solomon River.
Kimball dredge	Solomon River.
Newburg & Flower	Solomon River.
Moody Mining Co	Canyon Creek.

KOUGAROK DISTRICT.

Behring Dredging Co	Kougarok River.
Kelliher dredge	Kougarok River.

FAIRHAVEN DISTRICT.

Candle Creek Mining Co	Candle Creek.
Deering Dredging & Mining Co	Inmachuk River.

PORT CLARENCE DISTRICT.

Estabrook dredge	Windy Creek.
Welch & Doren	Budd Creek.

Most of the dredges now being operated are using distillate for fuel. The generation and delivery of power to the dredges from one or more hydroelectric plants, a project which has been under consideration for some years, was given new impetus in 1916 by two companies. The Wild Goose Mining & Trading Co. installed and made ready for operation in 1917 a hydroelectric plant on Ophir

Creek, in the Council district. A ditch with intakes at the heads of Ophir Creek and Casadepaga River will deliver 2,500 inches of water at claim No. 15 above Discovery on Ophir Creek, with a fall at that point of approximately 30 feet. The power thus generated will be utilized to run two dredges.

Another company has under consideration a dam and power site in the Kigluaik Mountains on Pass Creek, a tributary of Kruzgamepa River. During the summer of 1916 a corps of civil and mining engineers were at work at that locality making preliminary surveys and studying other details of the project. It is reported that this work will be continued in 1917. Detailed measurements of stream flow, extending over a number of years, are the prime essential for determining the feasibility of such a project, for the success of the undertaking seems to depend in large measure on the amount of water available at different times in the year. The transmission of power and the demand for it are likewise important details for consideration.

It is estimated that the 27 gold dredges on Seward Peninsula in 1916 employed 430 men and handled about 1,870,000 cubic yards of gravel, yielding gold to the value of $985,000, compared with the handling of 3,000,000 cubic yards of gravel, yielding $1,050,000, by 31 dredges in 1915.

Dredge operations on Seward Peninsula in 1916.

District.	Production (per cent).	Yardage (per cent).	Average value per cubic yard.
Nome	32	34	$0.50
Council	42	33	.66
Solomon	11	18	.33
Kougarok Fairhaven Port Clarence	15	15	.51

The average value per cubic yard of the gravel handled by the dredges for the whole peninsula is about 53 cents. From the above table it will be seen that the value of the gravel in the Nome district approaches the average value, while the gravel mined in the Council district is above the average and that of the Solomon district is below the average. From data at hand it is known that the Fairhaven gravel is near the normal value, the Kougarok considerably exceeds it, and the Port Clarence falls below it to a corresponding degree.

UNDERGROUND MINING.

Approximately 77 deep placer mines were worked on Seward Peninsula during the last year, most of them in the Nome district. It is estimated that 50 mines were worked during the winter and about 48 during the summer, employing in all about 400 men. The following list shows the distribution of the mines so far as they are known:

Deep placer mines worked on Seward Peninsula, 1916.

Nome district:	
Dexter Creek and Hill	12
Center Creek	12
Third beach line	15
Second beach line	4
Submarine beach	2
Present beach	1
Dry Creek	3
Irene Creek	2
Sledge Creek	2
Manila Creek	2
Cooper Gulch	1
Specimen Gulch	1
Anvil Creek	1
Wonder Creek	1
	59
Fairhaven district:	
Candle Creek and vicinity	6
Inmachuk River	2
Joseph Creek	1
	9
Solomon district:	
Solomon River	1
Koyuk district:	
Dime Creek	8

One feature of the underground mining worthy of particular mention is the development of a new placer camp on Dime Creek, a tributary of Koyuk River. Brooks[1] has described the location of this camp and has given some details regarding the extent of the pay streak and the earlier mining operations.

The distributing point for this camp is the town of Haycock, on the north bank of Koyuk River, about 3 miles above the mouth of Dime Creek. Most of the supplies and mining outfits have so far been brought in by way of Golovin, on the east side of Golofnin Bay.

The pay streak is 2 miles or more in length, and the auriferous gravel lies in a deep bench channel. All the mining so far has been done by drifting. The gold on Dime Creek is of remarkably high grade. One assay shows a fineness of 957 parts gold and 38 parts silver, which gives a value of $19.80 an ounce. Another assay is known to have shown a value of $19.77 an ounce, and a third a value of $19.84. With the exception of some of the Koyukuk gold, this is probably the highest grade gold found so far in Alaska. Dime Creek is also of interest on account of the occurrence of placer platinum with the gold.

It is estimated that the deep mines of Seward Peninsula produced during 1916 gold with a total value of about $528,000, of which more than $100,000 was taken from the deep mines on Dime Creek during the winter. In all, about 157,000 cubic yards of gravel was handled.

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[1] Brooks, A. H., The Alaska mining industry in 1915: U. S. Geol. Survey Bull. 642, p. 70, 1916.

OPEN-CUT WORK.

In all 62 open-cut mines, at 11 of which the hydraulic giant was used, were operated during the summer of 1916 on bench, creek, and beach gravels. The distribution of these mines, so far as known, is as follows:

Open-cut mines on Seward Peninsula, 1916.

Nome district:	
Nome Beach	10
Anvil Creek	2
Dexter Creek	1
McDougall Creek	1
Buster Creek	3
Twin Mountain Creek	2
Coffee Creek	1
Hazel Gulch	1
Moss Gulch	1
Oregon Creek	3
Glacier Creek	2
Wonder Creek	1
Rock Creek	1
Grass Gulch	1
Bangor Creek	2
Derby Creek	1
Willow Creek	1
Osborne Creek	1
	35
Solomon district:	
Casadepaga River	2
Moonlight Creek	1
Silver Bow Creek	1
Problem Creek	1
Daniels Creek	1
Big Hurrah Creek	1
	7
Council district	1
Kougarok district:	
Macklin Creek	3
Dick Creek	1
Kougarok River	2
Harris Creek	1
Miscellaneous	3
	10
Fairhaven district:	
Candle Creek	3
Bear Creek	2
Inmachuk River	1
	6
Port Clarence district:	
Dahl Creek	2
Gold Run	1
	3

Besides these, hydraulic elevators were at work at the following localities: Little Creek, 5; Boulder Creek, 1; Inmachuk River, 2; Ophir Creek, 2.

It is estimated that the open-cut placer mines handled 723,000 cubic yards of gravel, producing gold to the value of $1,437,000. About half of this output, or about 25 per cent of the total gold output of Seward Peninsula, was recovered by the hydraulic elevators. This is due in large measure to the remarkable richness of the placers on Little Creek. About 400 men were employed in the open-cut mines.

PRODUCTION.

In all, about 150 gold placer mines and 27 gold dredges were operated on Seward Peninsula in 1916. About 1,230 men were at work at these plants. The production of gold for the year is estimated to be $2,950,000, practically all of which was taken from the placers.

Gold and silver produced on Seward Peninsula, 1897–1916.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1897	725.63	$15,000	87	$52
1898	3,628.12	75,000	435	256
1899	135,450.00	2,800,000	16,254	9,752
1900	229,781.25	4,750,000	27,574	17,097
1901	199,822.61	4,130,700	24,579	14,747
1902	220,677.07	4,561,800	26,481	14,035
1903	215,994.38	4,465,000	24,171	13,052
1904	201,462.52	4,164,600	24,175	14,021
1905	232,200.00	4,800,000	27,864	16,997
1906	352,812.50	7,500,000	43,537	29,605
1907	338,625.00	7,000,000	25,497	16,828
1908	247,680.00	5,120,000	20,577	10,905
1909	207,077.50	4,260,000	20,871	10,853
1910	169,312.50	3,500,000	20,317	10,971
1911	149,962.50	3,100,000	17,996	9,718
1912	145,125.00	3,000,000	17,415	10,710
1913	120,937.50	2,500,000	12,094	7,305
1914	130,612.50	2,700,000	15,673	8,667
1915	140,287.50	2,900,000	17,510	8,878
1916	142,706.25	2,950,000	14,271	9,391
	3,593,880.33	74,292,100	397,378	233,840

TIN.

Two tin dredges, belonging to the American Tin Dredging Co. and the York Tin Dredging Co., were operated in the York district in 1916. The former was working upstream on Buck Creek, and the latter was at the mouth of Buck Creek, working downstream into Grouse Creek. Both dredges worked all summer and are reported to have had a successful season.

TUNGSTEN.

The presence of scheelite (calcium tungstate) on Seward Peninsula has been known to the Geological Survey for many years. Moffit,[1] in his report on field work done in 1905 and 1906, referred to the presence of scheelite in the placers and quartz veins of Seward Peninsula as follows:

> Tungsten occurs in the Nome region in the form of scheelite, the tungstate of calcium. It is a heavy white mineral, and is found in many of the streams. Because of its weight it remains in the sluice boxes or pan and causes some trouble in cleaning the gold. Scheelite is also found associated with quartz in small veins in the schist, but its principal source is the gold-bearing gravel.

Within the last two years the high price of tungsten has rendered the recovery of scheelite profitable on the peninsula, and it is now possible that scheelite mining may become an established industry.

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[1] Moffit, F. H., Geology of the Nome and Grand Central quadrangles, Alaska: U. S. Geol. Survey Bull. 533, p. 134, 1913.

The most extensive scheelite mining operations were carried on by the Pioneer Mining Co., on Sophie Gulch, an eastern tributary of Rock Creek. On the south side of Sophie Gulch, at an elevation of about 300 feet, a scheelite-bearing lode has been opened, and the decayed residual material was worked during the summer of 1916 by placer-mining methods. This lode and its mineralization will be described in a separate publication dealing with the tungsten resources of Alaska. Between 4,000 and 5,000 cubic yards of the shattered and weathered residual lode material has been removed by hydraulicking and run off into a narrow cut through sluice boxes. It is necessary, in this work, to clean up four times a day, on account of the amount of quartz and other rock handled and on account of the bulkiness of scheelite as compared with the precious metals. Naturally in such work a considerable amount of the scheelite is lost with the tailings, as the nozzle can break to pieces only the material that is much weathered and disintegrated. To remedy this loss, the owners are contemplating the installation of a plant to mill the lode material before sluicing. Mining on the Sophie lode had been in progress for six weeks at the time of the writer's visit, October 7, and it is reported that the lateness of the fall enabled the operators to continue work for two or three weeks longer. This mine produced a large part of the scheelite mined in Alaska in 1916.

Smaller lodes, essentially similar in character to the one above described, were worked in a small way by the Pioneer Mining Co. Thus, on Twin Mountain Creek, on a right-hand bench claim opposite claim No. 4 above Discovery, about 500 pounds of scheelite was said to have been sluiced from a weathered lode. Likewise the Lynx claim, on the north side of Glacier Creek, just above the Guinan & Ames dredge, was worked by the same company. At this locality a shaft was sunk 60 feet, and the lode material, consisting of scheelite, quartz, and iron-stained schist, was raised to the surface and sluiced. It is reported that about 600 pounds of scheelite was recovered.

Another small lode of similar character, on the Glacier-Rock Creek divide, was prospected by Stipek & Kotovic and found to carry scheelite.

Placer-mining operations for scheelite were also carried on by the Pioneer Mining Co, and by J. Warren and partners on Rock Creek. The Warren party operated on claim No. 2 above Discovery.

The Guinan & Ames dredge, operating on Glacier Creek, saved the scheelite from the concentrates taken with the gold in 1916, and another dredge on Sunset Creek, in the Port Clarence district, is reported to be planning to do the same. Other gold placer operators are also beginning to save the scheelite from their concentrates.

PLATINUM.

Placer platinum was found in the gold placers on Dime Creek, in the Koyuk basin, in 1916. It was reported to the writer that the platinum is present in the gravels on Greenstone Creek, a tributary of Dime Creek, and also on Dime Creek below the mouth of Greenstone Creek. This metal in commercial amount has been recovered by at least two operators, and probably also by others. An analysis of some of the platinum from Dime Creek, made in the chemical laboratory of the Geological Survey by R. C. Wells, showed that the material submitted contained 71.5 per cent of platinum. The analysis showed also 11.5 per cent of silver, lead, and gold, which was probably due in large measure to fine gold in the sample. On recalculation exclusive of these elements the platinum appears to be 81 per cent fine. The impurities in the alloy are iron, iridium, osmium, palladium, and copper, named in their order of relative abundance.

Placer platinum was also discovered in 1916 on Bear Creek, in the Fairhaven district, about 35 miles in an air line north of Dime Creek. The details of this discovery are not yet known, but returns from the placer operators show that at least one operator on Bear Creek has recovered platinum in the gold placers.

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RECENT SURVEY PUBLICATIONS ON ALASKA.

[Arranged geographically. A complete list can be had on application.]

All these publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained free of charge (except certain maps) on application.

2. A certain number are delivered to Senators and Representatives in Congress for distribution.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost. The publications marked with an asterisk (*) in this list are out of stock at the Survey, but can be purchased from the Superintendent of Documents at the prices stated.

4. Copies of all Government publications are furnished to the principal public libraries throughout the United States, where they can be consulted by those interested.

The maps whose price is stated are sold by the Geological Survey and not by the Superintendent of Documents. On an order amounting to $5 or more at the retail price a discount of 40 per cent is allowed.

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*The geography and geology of Alaska, a summary of existing knowledge, by A. H. Brooks, with a section on climate, by Cleveland Abbe, jr., and a topographic map and description thereof, by R. U. Goode. Professional Paper 45, 1906, 327 pp. No copies available. May be consulted at many public libraries.

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*The mining industry in 1906, by A. H. Brooks. In Bulletin 314, 1907, pp. 19–39. 30 cents.

*The mining industry in 1907, by A. H. Brooks. In Bulletin 345, 1908, pp. 30–53. 45 cents.

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Kasaan Peninsula, Prince of Wales Island (No. 540A); scale, 1:62,500; by D. C. Witherspoon, R. H. Sargent, and J. W. Bagley. 10 cents retail or 6 cents wholesale. Also contained in Professional Paper 87.

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Circle quadrangle (No. 641); scale, 1:250,000; by T. G. Gerdine, D. C. Witherspoon, and others. 50 cents retail or 30 cents wholesale. Also in *Bulletin 295. 35 cents.

Fairbanks quadrangle (No. 642); scale, 1:250,000; by T. G. Gerdine, D. C. Witherspoon, R. B. Oliver, and J. W. Bagley. 50 cents retail or 30 cents wholesale. Also in *Bulletins 337 (25 cents) and 525.

Fortymile quadrangle (No. 640); scale, 1:250,000; by E. C. Barnard. 10 cents retail or 6 cents wholesale. Also in Bulletin 375.

Rampart quadrangle (No. 643); scale, 1:250,000; by D. C. Witherspoon and R. B. Oliver. 20 cents retail or 12 cents wholesale. Also in *Bulletin 337 (25 cents) and part in Bulletin 535.

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